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FORMS AND CONDITIONS OF MIGRATION OF SUBSTANCES IN THE SOIL PROFILE (Review of Foreign Literature)

I. N. ANTIPOV-KARATAYEV and I. G. TSYURUPA

As we know, the structural soil profile is heterogeneous. This is due to the fact that in the course of soil formation the parent material acquires a different composition in its various layers, and as a result soil horizons form. The forms of migration of simple salts and their accumulation in particular soil layers are sufficiently clear, since they usually move in the form of solutions. A vast literature is devoted to the pattern of salt movements with soil solutions and their transformations during exchange reactions with the solid phase of the soil. In the present paper we feel that it is superfluous to discuss this aspect of the problem.

The most complicated and disputed aspects of the problem are: 1) the possibility of the infiltrational movement of finely dispersed fractions of the soil; 2) the conditions of the transition of non-readily soluble soil compounds to colloidal soluble forms and the migration of the latter in the soil profile; and 3) the conditions of formation of molecularly soluble complex compounds and their movement along the soil profile.

Let us examine these problems for in the last 20 years they have acquired a great importance, being used to explain the mechanics of the formation of illuvial soil horizons.

We feel that it is best to use a complex of three methods: 1) comparative geography, 2) experimental-field, and 3) laboratory-experimental methods in the investigation of these problems. Only by a combination of these methods can we exhaustively solve these complicated problems.

The problem of the infiltrational movement of finely dispersed soil fractions (suspension) is of interest to soil scientists in relation to the theory of the development of illuvial horizons (hardpan and claypan) in the soils of the acid series and in solonetzes. Podzolic soils with an illuvial horizon having a clay fraction similar in composition to the clay of the other soil horizons, including the eluvial horizon, have been discovered in recent years. From this it has been concluded that the illuvial horizon in these soils had developed by the infiltrational movement of clay from the eluvial horizon.

The same was also found in the solonetzic soils of the neutral series (the so-called steppe-like soils in the chestnut zone). The use of comparative geography in the study of this problem made it possible to determine those conditions of the medium under which the peptization-infiltration process of clay movement creates an illuvial horizon in soils of the acid series. Skeen (75) determined the pH of 45 soils in Pennsylvania having a hardpan at various depths in the profile and found that the infiltrational movement of clay and hardpan formation took place at a soil solution pH of not less than 4.75-5.2. In those cases when the pH was lower, the decomposition products of the clay mineral fractions were brought into the illuvial horizon. Later, Richardson (67) investigated the composition of eluvial, illuvial, and parent material horizons of Florida soils, which are of a coarse texture and characterized by the presence of hardpan and parallel to it those without hardpan. In these soils the illuvial (hardpan) horizons were undoubtedly formed through peptization-infiltration without the decomposition of the clay, since, first of all, the pH did not drop below 5.0 in any of the soil horizons, and, secondly, the Fe_2O_3, Al_2O_3, and CaO content was the same in all the soil horizons investigated with and without hardpan; consequently, the change in the clay content in the illuvial horizon was only quantitative and not qualitative. The infiltrational movement of clay was due to the peptizing effect of the organic matter in the soil, which is evidenced by the relative increase of the humus content in illuvial horizons as compared to the corresponding soil layers without hardpan. Soils with the same mechanisms of formation of illuvial horizons have been described in many countries (U. S., Germany, France, England, Romania, etc.).

The first attempt at characterizing such soils in the USSR was made by Fridland (4), who called the formation of illuvial horizons by the peptization-infiltration process illimerization. German and Swedish authors, such as Müchenhausen,[1] Kubiena (53), and Palmann (62), ascribe the peptizing role of the clay fraction of soils to molecularly and colloidally dispersed free silica. According to the data of these authors, the source of peptizer-silica are the decomposition products of primary soil minerals, i. e., with such mechanisms of illuvial horizon formation we can hardly speak of a pure infiltration process. In fact, Palmann's data on the chemical composition of the various horizons of brown forest soils, considered by this author as representative of soils with an illimerized illuvial horizon, show that the composition of sesquioxides differs in the eluvial and illuvial horizons of these soils.

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[1] Personal communication to I.N. Antipov-Karatayev.

Field and laboratory experiment methods were also used to solve the problem of the possibility and magnitude of the infiltrational movement of the peptizing organic substances of clay particles along the soil profile.

Field investigations included those of Sokolovskiy (3) on the artificial solonetzization of various soil materials, in the course of which a water-impermeable layer forms by infiltration from the peptized clay mass.

The depth of penetration of the organic peptizer into loess reaches 20-40 cm, according to the data of Dumanskiy. Illner (46) conducted field experiments on the foregoing problem on sandy loam soil, using various fractions of fluorescent glass. The results of these investigations showed that the finely dispersed (<0.1 mm in diameter) silicate (glass) fraction migrates in coarsely-textured soils to a considerable depth (the experiment was made during a period with little precipitation — about 56 mm in 2 months) with vertical water flow. Among laboratory experiments (primarily qualitative), the most interesting are the well-known investigations of Jenny and Smith (45) on the filtration of a sodium clay suspension, separated from Putnam clay, through columns of quartz powder of varying dispersion. It follows from the results of these investigations that the mechanism of the passage of a clay suspension with negatively-charged particles through a column of negatively-charged sand or coarsely-textured soil is analogous to sieving, and finely-dispersed particles can only move in the soil pores. Calculations show that spherical particles form channels of such diameter in the filtration column through which similarly-charged clay particles filter freely. These authors came to the conclusion that colloidal suspensions are not arrested mechanically (by sieving) in relatively coarse soils, but are fully stopped in fine-textured soils. Therefore, illuvial horizons cannot form in such soils by the infiltration of the suspension. Organic soil substances (Na-humate) had a stabilizing effect on the filtrating clay suspension.

Thus, the formation of illuvial horizons by suspension-infiltration is quite limited. The migration of substances in the form of colloidal dispersions, which leads to the formation of illuvial soil horizons (in particular, in solonetzes) by colloid-infiltration, is somewhat less limited.

As mentioned earlier, a necessary premise for this substance-migration mechanisms is the decomposition of soil materials into components and their acquisition of a negative charge, i. e., same as that of the capillary system of the soil, in order to eliminate the possibility of a mutual electrovalent attraction of these two systems. Comparative-geography investigations show that the chemical heterogeneity of the profile of most acid soils is determined by the relative accumulation of free sesquioxide hydrates, such as manganese, sometimes humic substances, and SiO_2, in the illuvial horizon. In order that iron and aluminum hydroxides migrate freely in the soil profile, it is necessary that their colloidal solutions be stabilized by recharging. Unfortunately there are only single field experiments on this problem (1, 47). Most of the results of these studies had not been discussed from the point of view examined. More material has been obtained by laboratory experiments, primarily on the stabilizing conditions of negatively-charged iron and aluminum sol complexes with SiO_2, MnO_2, PO_4, and organic compounds, including humic acids. These investigations established the optimum pH limits, the relationship between mutually stabilizing components, etc. Demolon and Bastisse (29, 30) obtained the following data on the zones of resistance of a number of complex sols to the coagulating effect of electrolytes: iron phosphates, pH 6.5-11; iron humates, pH 5.0-9.5; iron silicates, pH 4.0-10.5; aluminum phosphates, pH 6.8-11.0; alumino-humates, pH 10.0; and alumino-silicates, pH 8.4.

Iron-silica sols had the highest coagulation threshold with respect to calcium salts. Investigations on infiltrational migration through columns of silty clay loam lead to the following conclusions:

1) iron-silica sol filtered freely through calcareous clay loam (with 14% $CaCO_3$) without changing; 2) there was no fixation of this sol on the negative surfaces of clay particles; 3) there was a certain coagulational precipitation of the sol in the clay suspension in the presence of $CaCO_3$, but the coagulation process proved to be reversible; and 4) iron humate sols proved to be stable on filtration through a dolomite column.

The foregoing data can be applied to the development of neutral or alkaline soils, but it is difficult to use them to explain the migration of sesquioxides in acid (podzolic) soils, since here primary minerals must decompose first and their components be dissolved, and then only (at a certain stage of migration) can they change into the colloidal state.

Therefore it is most logical to think that illuvial horizons form in acid soils (podzolic) through molecular infiltration. Iron and aluminum must change from primary minerals or from a hydroxide state into a stable true solution and migrate in this form in the soil profile to such zones, where their stability conditions are disturbed (Barbier [9]). The investigations by a number of authors (including those of our laboratory) show that such stable compounds are negatively-charged molecular iron and aluminum chelates. Such compounds can form in soils as a result of the action on the minerals of organic compounds released by the root systems of plants or forming during the decomposition of plant remains under the action of microorganisms.

The term "chelate-like complex" or "chelates" was suggested in 1920 by Morgan and Drew (quoted from Scheffer, 72) for compounds consisting of a central metal ion and its surrounding organic molecule radicals. The authors introduced the concept of two-, three-, and four-tooth chelates (depending on the number of places in the molecule in which they are bound with the metal).

At the present time we call chelates the group of ring compounds with a chain is the complex of iron with ethylenediaminetetracetic acid (EDTA for short).

According to Scheffer, Ulrich, and Hierstermann (72, 73), there are the following distinctions between ordinary complex compounds: in complex compounds each radical is bound by only one coordinate bond with the central ion, while in chelate compounds the radical of the molecule (usually organic) is connected with the central ion by several coordinate bonds. In this case a ring connection forms within the limits of the radical (between groups capable of giving off ions). These authors represent the difference between ordinary complex compounds and chelate compounds by the scheme shown in Fig. 2.

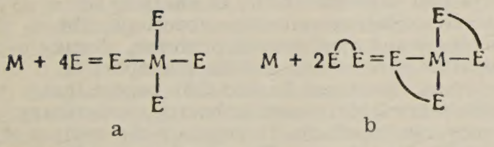


Fig. 2. - Schematic representation of a complex and an iron chelate with an organic radical. a - simple metal complex; b - chelate; M - metal ion; E - radical.

The basic difference between ordinary complex compounds and chelate compounds is also emphasized by Martell and Calvin (59).

Many investigators were concerned with the study of chelates. The main conclusions on this problem can be formulated in the following way:

1. The stability of chelates depends on the state of stress of their ring system. The least stresses occur in five-tooth chelates (65).

2. The central ion of a chelate can be replaced by metal soil cations (51, 56).

3. The exchange rate of the central metal ion of chelates depends on the nature of the bonds, the structure of the complex-producer, and especially on the metal in the complex (20).

4. Chelate compounds of heavy metals with EDTA and similar complex-producers are photosensitive and decompose under light, producing metal hydroxides and oxidation products of the complex-forming radical (21, 33, 34, 36, 74).

5. The stability of chelates depends on the conditions of the medium. Thus, a chelate of iron and EDTA is very stable in an acid medium. The OH ions begin to unite with it at a pH > 7.5. At a pH > 10 the carboxyl groups in the central ion become partially replaced by hydroxyl groups, which is accompanied by the precipitation of $Fe(OH)_3$ and the decomposition of the complex (74).

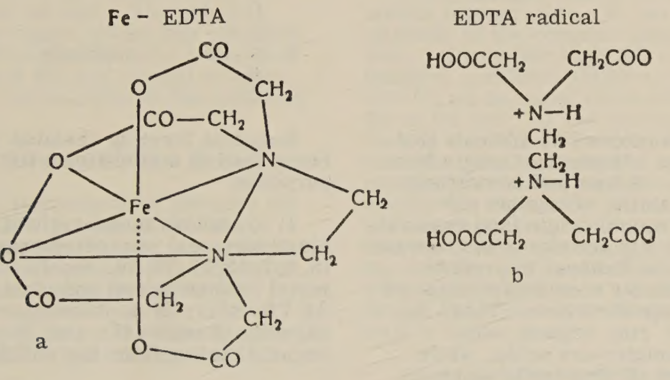
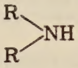
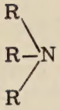
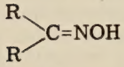
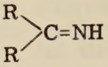
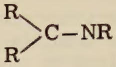
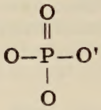
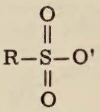


Fig. 1. - Schematic representation of an iron and ethylenediaminetetracetic acid (EDTA) chelate.
a - Fe-EDTA chelate; b - EDTA radical.

6. Chelates are not metabolized by soil microorganisms, but are taken up whole (44, 88).

The last conclusion is disputed by Barshad (10), however, who maintains that the organic part of chelate compounds is decomposed by soil microorganisms, while iron and aluminum are released and deposited in the form of hyhydroxides.

The formation of chelate compounds is caused by very many reagents. Martell and Calvin (59) give the following list of organic groups which actively form chelates:

$R-NH_2$	primary amines
	secondary amines
	tertiary amines
	oximes
$R_2-S{=}O$	thioketo group
$R-O'$	hydroxyl group
$R-COO'$	carboxyl group
	imines
	substitute imines
$R-S-R$	thio ethers
$R_2-C{=}O$	keto group
 $O-\overset{\overset{O}{\Vert}}{\underset{\underset{O}{\vert}}{P}}-O'$	phosphonate
 $R-\overset{\overset{O}{\Vert}}{\underset{\underset{O}{\Vert}}{S}}-O'$	sulfonate

Mandle and collaborators (57) indicate that very many substances of biological origin form chelates with metals. Schatz and co-workers (68-71) mention the ability of organic substances of plant and animal origin (and especially the products of the life activity of microorganisms, mycorrhiza, and lichens) to produce with metal cations soluble coordinated covalent compounds with a ringe structure. These authors emphasize that ring organic substances producing chelates are acids, while others are alkali, but all bind in the same manner and produce compounds of one and the same type.

Hutner and collaborators (44), and Scholz (74) report that the acids released by the rhizosphere of roots (citric, malic, tartaric, etc.) form chelates with the metals of soil colloids. Finally, certain authors (11, 13, 18, 20, 49) obtained chelates from metals and organic substances separated from the soil.

It must be emphasized that in spite of the large number of compounds capable of producing chelates with metals, only a very small number of organic groups is capable of chelate formation (see the list of these groups, given by Martell and Calvin, above). Scheffer (72) states that the only elements forming a coordinate bond with metals and filling the electron configuration of the central atom are nitrogen, oxygen, and sulfur.

Chelates and the reagents producing them are now being widely used in analytical chemistry. A new section of chemistry has developed — chelatometry, which is based on the determination of metal cations in the form of their chelates.

Reagents forming chelates with metals are being used in soil analysis for the following purposes:

1) to remove metal cations, primarily iron, aluminum, and microelements, from the soil (5, 6, 7, 43, 77, 78, 86, etc.); 2) to determine metal cations in soil and plant extracts (12, 24, 77, etc.); 3) to determine the exchange capacity of soils (48); and 4) to remove the organic matter from the soil (19, 60, etc.).

A tremendous number of papers in recent literature is devoted to the importance of chelates to the life of animals and plants. This is only natural, since chelates are active participants in the majority of physiological processes and reactions. Thus, Martell and Calvin (59) note the ability of chelates to catalyze oxidation-reduction reactions, the hydrolysis and synthesis of proteins, decarbonization processes, and the transport of electrons. Hart and Laszlo (35) report that chelates are widely used in botany, veterinary science, and medicine to regulate the regime of metals in organisms. The regulating role of chelators in the regime of metals in biological systems has also been noted by Chaberek and collaborators (23).

Many investigators (26, 27, 31, 58, 59, 66, etc.) have established that chlorophyll, hemins, and certain ferments and enzymes are chelates in which the metal (iron, copper, molybdenum, and magnesium) is very strongly bound with the organic complex-producer and can be released only after the complete decomposition of the molecule of the given substance.

The active participation of chelates in enzyme and fermentation processes makes them an important factor in the formation of the organic matter in soil.

Extensive material has been collected on the problem of the role of chelates in plant nutrition. Gile and Carrero (32) showed as early as in 1916 that iron citrates and tartrates can be successfully used for plant nutrition, since they remain in a dissolved state longer in neutral and alkaline media than iron sulfate. Hoagland (40) substantiated these data in 1919. However, chelates came to be widely used in agronomy after the work of Hutner and collaborators (44), who, in 1950, suggested the use of EDTA for the control of chlorosis caused by iron deficiency. The investigations of many authors confirmed that iron chelates are good sources of plant nutrition, even under alkaline conditions (41, 50, 52, 54, 76, 79-83, 87, 92, etc.).

Perkins and Purvis (63, 64) established in 1954-1955 that after chelates are added to the soil, the amount of available Mn, Ca, Mg, K, and, especially, Fe in it increases. The change of various elements (micro-elements, in particular) to a state available to plants is explained by the authors by the substitution of the metal in the chelate by metals in the adsorption complex of the soil. The use of chelates containing tagged atoms has revealed the presence of exchange reactions between these compounds and the soil or soil solution (51, 55, 56, 87-91), taking place in the following manner:

$$Fe^x\text{—EDTA} + Fe\text{—X} \rightleftharpoons Fe\text{—EDTA} + Fe^x\text{—X}.$$

Noting the great importance of chelates for agronomy, Schatz (68) points out that the main role of "chelate fertilizers" consists in the removal of microelements from minerals and their change into a state available to plants. The same conclusion on the role of chelates follows from the work of Swaby and Passey (84), and Miller and Ohlrogge (61).

A number of authors (22, 38, 41, 56, 87-91) established that certain chelates (Fe-EDTA, for instance) become irreversibly fixed at the surface of clay particles in the soil and are lost to plants, while others (Mn-EDTA and Zn-EDTA) do not become fixed by the soil. The metal in chelates, added to sandy soils, is practically not fixed and remains in a form available to plants. Discussing the data on the fixation of chelates in soils, Lunt (56) comes to the conclusion that the disappearance of iron under alkaline conditions is partly attributable to its precipitation in the form of a hydroxide. He finds the mechanism of the fixation of Fe under acid conditions obscure.

Noting the possibility of the fixation of chelated micro-elements by the clay portion of soil, Wallace and collaborators (87, 89) stress the necessity of taking into consideration the properties of chelates and complex-producers when using them for practical purposes, since the improper use of these compounds may cause the fixation of nutrients, and not their release, and result in a degradation of the nutrition of plants.

The use of Fe-EDTA and Na_2-EDTA, containing tagged atoms, showed that plants take up chelates in the form of whole molecules. Later, the absorbed chelates decompose and the elements released thereby are used for the formation of tissues (37, 41, 88. 90).

Certain authors note the toxic effect of chelates on plants (41, 90, 91), explaining it by the ability of chelates to affect the metal-enzymic functions of the organism, to catalyze protein hydrolysis and synthesis, etc. It is possible that the toxic effect of chelates is caused in individual cases by the increase of the concentration of nutrients in the soil solution above the amount necessary for plant development.

The first mention of the existence of chelates in soils is found in the paper of Horner and collaborators (42). These authors believe that the transition of iron into a form available to plants is caused by chelators in soil humus. Later chelates were obtained by many authors from metal and organic soil substances (11, 13, 18, 20, 49). Studying the properties of these compounds, Broadbent and Ott (20) established the following:

1) the organic matter in the soil fixes metals irreversibly, 2) the cation fixation intensity in the complex depends on their valence (the higher it is, the stronger the fixation) and their ability to form a complex (the Cu ion is bound more strongly than the Ba or Ca ion); 3) the amount of the complex formed depends on the initial cation concentration (the smaller it is, the more intense is complex formation) and the pH (the higher the acidity is, the weaker is complex formation), but is independent of the interaction time (the reaction takes place very rapidly); and 4) the stability of complexes of organic matter with various metals is almost the same, even though the following tendency is noted: $Cu > Ba = Ca > Mg$.

Himes and Barber (39) studied the formation of chelates in the soil by means of radioactive zinc. They found that 1 g of coarse clay loam alluvial soil, containing 9.4% humus, is capable of chelating about 50 micromoles of zinc. Chelates formed only with the participation of an organic substance: after humus was removed chelation ceased. The increase of the amount of zinc added above a certain limit had an unfavorable effect on the mobilization of nutrients and their uptake by plants.

Schatz and collaborators (68-71) report that chelates have a greater effect on the decomposition of rocks and minerals than is generally assumed. Without denying the role of organic acids in the process of biochemical weathering, this author believes that the decomposition of rocks and minerals is caused primarily by chelation. Taking into consideration the abundance of microbic and plant products having the ability to chelate, the stability of organo-metallic chelates, and the wide pH interval at which the formation of chelates is possible, Schatz notes the tremendous importance of chelates for soil formation and considers chelation as an independent and very important factor in weathering, differing qualitatively from chemical weathering under the influence of organic acids.

Swidele and Jackson (85) also believe that the formation of chelates is the main reason for the weathering of rocks and minerals. They introduced the term "cheluviation" by which they mean the decomposition of minerals under the action of organic substances and the subsequent removal of soluble products by water. In their opinion, the accumulation of Fe and Al oxides in the lower part of the soil profile is an evidence of the development of cheluviation in the upper soil layer. Bloomfield (14-17) came to the conclusion that water extracts from leaves, needles, and forest litter dissolve sesquioxides because of chelation. De-Long and Schnitzer (28) also investigated solutions forming when atmospheric precipitation infiltrates through forest litter and found that these solutions were capable of removing Fe, Al, and Ca from the soil and Fe from Fe(OH)$_3$. However, analyses of the extracts obtained gave opposite results: potentiometric titration revealed the presence of chelation, but a large part of the iron, removed in the extract, was in the form of free ions, and the products obtained did not give light absorption maxima characteristic for chelates. Therefore, the authors believe that they have not obtained exhaustive proof of the formation of chelates and that the main function of organic matter consists in its peptizing and protective effect on colloids.

Deb (25) acknowledges the possibility of the mobilization of iron in soil in the form of chelates, but notes the difficulty of proving its movement along the soil profile in the form of such compounds.

The experiments of Atikinson and Wright (8) on the vertical movement of chelates in the soil and their role in the formation of illuvial horizons are very interesting. They leached columns of calcareous sand with a small content of humus with water and weak EDTA solutions (pH 4.9) for 16-17 months. At the end of the experiments they found an almost unnoticeable change in the color of the sand in the columns leached with water, and the presence of pronounced colored layers in the columns leached with EDTA. Analyses revealed a noticeable mobilization of Fe, Al, Ca, Mg, and Si, and their transport from the upper to the lower layers and partial removal beyond the limits of the columns. The accumulation of Fe and Al along the profile of the columns corresponded to the colored layers of the sand. Figure 3 shows curves of the distribution of sesquioxides and particles $< 2\ \mu$ in diameter in the columns leached with water and EDTA. The foregoing authors believe that the distribution of the clay fraction and of the "readily-soluble" forms of Fe and Al disprove the hypothesis of the transport of these elements in the form of an oxide film at the surface of clay particles. Noting the noticeable dissolving effect

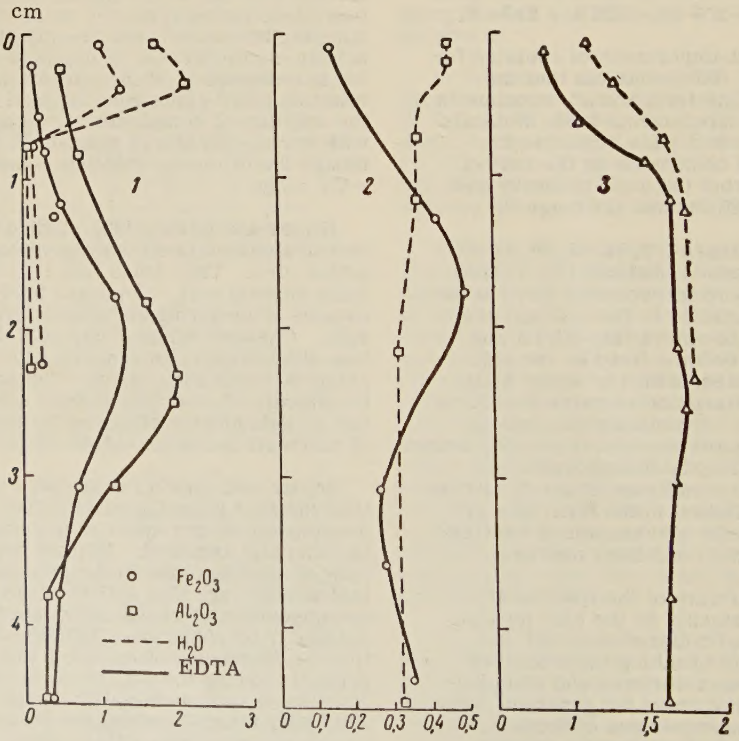


Fig. 3. - Distribution in columns leached with water and EDTA. 1 - sesquioxides removed with hot 0.2 N HCl; 2 - Fe_2O_3 extracted with sodium hydrosulfite; 3 - particles $< 2\mu$ in diameter.

of EDTA on the soil, the authors stress the possibility of the creation of an undesirable nutrient regime when using chelators for agricultural purposes.

This review of the foreign literature on the role of chelates in various natural processes embraces only papers of greatest interest to soil scientists. But even the material presented shows how widely distributed and important these compounds are in nature. These data indicate the necessity of studying the process of soil formation from a new point of view, dictated by the present state of our knowledge of the chemistry of chelate compounds.

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INVESTIGATION OF THE MICROFLORA IN THE CULTIVATED PEAT SOIL OF THE YAKHROMA RIVER VALLEY

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We know from the data available in the literature that peat beds and humic-peat soils of the lowland type are populated by various groups of microorganisms capable of decomposing and mineralizing plant residues and releasing mineral nutrition elements.

Kurbatova-Belikova (3, 5, 6, 7, 8), Shtrobinder (20), Simakova (16), Rubenchik and Goykherman (12), Mal'chevskaya (10), Aleksandryan (1, 2), Vyvulo (4), Lupinovich and Golub (9), Ozolin' (11), and others report the presence of a large number of ammonifiers and butyric bacteria in peat beds and humic-peat soils: they found anaerobic and aerobic nitrogen-fixing and cellulose-decomposing bacteria.

The process of ammonification is always intense, independent of moisture. Nitrification is depressed in natural peat beds, but intensified in drained humic-peat soils, especially during their agricultural reclamation.

The present study is part of a complex investigation of the genesis of humic-peat soils and the modification of their properties on melioration and cultivation. Because of the recent development of vegetable growing on the flood-plain soils of the non-chernozem zone, the comprehensive study of these soils, including their microflora, acquired a special importance.

We studied the active and potential microflora in cultivated peat soils in various parts of the flood plain:

1) clay-peat soil along the river, Profile 54; 2) iron humic-peat soil in the central part of the flood plain under grass, Profile 56; 3) the same soil in fallow, Profile 61; 4) iron-calcareous humic-peat soil along the terrace of the flood plain under grass, Profile 58; and 5) and the same soil in fallow, Profile 58^a.

The present article contains the results of investigations from 1953-1956. These soils are described and characterized in the papers of Skrynnikova (17, 18, 19). The foregoing soils have a number of ecological features which determine the composition of microorganisms and the nature of processes taking place in these soils.

The plowed layers of claypeat soils are characterized by a stable structure and have the most favorable water-air regime. A large place is occupied by iron in the ash composition of iron humic-peat soils and the structure of these soils is less stable. Iron-calcareous humic-peat soils have the least favorable water-physical properties. Secondary waterlogging takes place here under the long-term cover of perennial grasses.

We studied the potential microflora by investigating physiological groups, the usual method in soil microbiology. The active microflora was studied by the method of agarized growth glasses, described by us earlier (14).

The results of investigations on the potential microflora of clay-peat and humic-peat soils under perennial grasses showed that their microflora contains various groups of microorganisms capable of generating processes associated with the carbon and nitrogen cycle. As we can see from Table 1, which shows the seasonal fluctuations in the number of bacteria (growing on beef-peptone agar) fungi, and actinomyces, the number of bacteria in these soils is in the millions. In July-August they penetrated to a considerable depth, up to 60-70 cm, which is apparently associated with the warming of the soil and the development of the root system of plants during this period. The number of spore-forming bacteria in these soils varied from 4%-46% of the total number of bacteria growing on beef-peptone-agar.

Fungi and actinomyces belong to a group of organisms with a strong fermentation apparatus. The literature mentions that they are capable of decomposing various, non-readily available nitrogen- and carbon-bearing compounds. The number of fungi is small in these soils and they are concentrated almost exclusively at a depth down to 10 cm. The number of actinomyces is considerable, varying from hundreds of thousands to 2-2.2 millions. They are found to a depth of 30 cm.

Anaerobic nitrogen-fixing bacteria of the type of Clostridium pasteurianum were found in all the soils investigated in thousands, and more rarely in tens of thousands per 1 g of soil; they were found both in the upper as well

Table 1

Number of microorganisms in clay and humic-peat soil of the Yakhroma River flood plain (1000/g of dry soil)

Group of microorganisms	Date of inoculation	Clay-peat soil				Iron humic-peat soil						Iron-calcareous humic-peat soil						
		Profile 54, grasses				Profile 56, grasses			Profile 61, fallow			Profile 58, grasses				Profile 58, fallow		
		Bacteria growing on beef-peptone-agar																
		3—10	20—30	40—50	65—70	5—10	20—30	40—50	5—10	15—20	35—40	5—10	20—30	40—50	60—70	5—15	20—30	40—50
Bacteria growing on beef-peptone-agar	June 9, 1954	10 454	3900	2141	—	5200	7810	5235	—	—	—	14 698	3522	6026	—	—	—	—
	July 19	1707	580	—	491	22 260	34 666	2273	—	—	—	2875	27 250	—	21 939	—	—	—
	August 20	3808	8544	—	69 396	26 848	31 147	87 662	—	—	—	11 003	355 550	—	92 380	—	—	—
	July 11, 1955	—	—	—	—	21 655	2313	2453	17 528	20 576	Few	12 432	—	16 187	1578	1750	—	—
	June 3, 1956	—	—	—	—	18 260	6300	—	7098	722	—	4343	1339	—	—	12 762	8103	—
	July 3	—	—	—	—	1651	—	1737	2200	—	444	3534	—	60	—	1461	—	60
	September 5	—	—	—	—	8562	194 500	130 400	18 029	7456	12 078	10 900	32 900	13 192	—	13 905	8355	22 959
Fungi	June 9, 1954	25	2,8	—	—	14	6	1	—	—	—	9	0,4	0,5	—	—	—	—
	July 19	5	12	—	0	15	0	0	—	—	—	0,9	0	—	0	—	—	—
	August 20	329	95	—	—	10	3	13	—	—	—	2	3	—	1	—	—	—
	July 11, 1955	—	—	—	—	7	9	0	0	0	0	0	—	0	0	100	—	—
	June 3, 1956	—	—	—	—	12,6	6	0	12	1,6	1	1,9	0	—	—	7,6	4,6	—
	July 3	—	—	—	—	32	—	37	180	—	0	3,6	—	0	—	3	—	0
	August 16	—	—	—	—	44	1	28	14,5	0	0	3	0,8	0	—	6	0	0
Actinomyces	June 9, 1954	939	400	50	—	405	36	0	—	—	—	534	6	5	—	—	—	—
	July 19	708	289	—	9	162	10	3	—	—	—	91	0	—	0	—	—	—
	August 20	493	1870	—	0	238	24	0	—	—	—	322	0	—	0	—	—	—
	July 11, 1955	—	—	—	—	1034	827	359	1292	—	29	400	—	0	0	—	—	—
	August 16,1956	—	—	—	—	1631	59	300	2175	21	0	680	17	0	—	700	0	0

as in the lower soil layers (from a depth of 60-70 cm), even though their number in the lower soil layers was lower, as a rule.

The Azotobacter grew systematically when iron-calcareous peat-bog soil was inoculated (Profile 58); 0%-100% of the soil blocks were overgrown by this organism at various periods of analysis, as we can see from Table 2. The Azotobacter grew only sporadically on blocks of ferrous peat soil (Profile 56), the maximum percentage of overgrowth reaching only 40%. Those soils where the Azotobacter grew only occasionally were systematically overgrown

Table 2

Number of Azotobacter and lipomycetes in humic-peat soil, % of overgrown soil blocks

Inoculation date	Iron humic-peat soil				Iron-calcareous humic-peat soil			
	Pro. 56, grasses		Pro. 61, fallow		Pro. 58, grasses		Pro. 58, fallow	
	Azotobacter	Lipomycetes	Azotobacter	Lipomycetes	Azotobacter	Lipomycetes	Azotobacter	Lipomycetes
June 19, 1954	0	—	—	—	46	—	—	—
July 19	0	—	—	—	100	—	—	—
August 21, 1955	0	—	—	—	68	—	—	—
Aug. 28, 1955	0	100	33	4	100	0	20	0
September 21, 1954	0	100	0	23	10	0	98	0
June 3, 1956	20	10	80	0	75	0	95	0
July 8, 1956	40	30	17	30	90	0	47	0
August 17, 1956	0	92	0	32	25	5	77	0
May 10, 1957	0	100	6	34	50	4	94	0
August 17, 1957	—	—	—	—	100	0	82	0
September 9, 1957	0	100	—	—	72	0	94	0
July 18, 1958	2	94	—	—	0	0	49	0
August 17, 1958	14	78	—	—	6	18	100	0

Table 3

Decomposition of cellulose in the soil under natural conditions

Profile No. and soil	Depth of cellulose placement, cm	Initial weight, g		Assessment after									
				28 days, July 3		52 days, July 27				95 days, Sept. 8			
		paper	cloth	paper		paper		cloth		paper		cloth	
				wt. g	% loss	wt. g	% loss	wt. g	% loss	wt. g	% loss	wt. g	% loss
58 Iron-calcareous humic-peat soil	7—10	1,5	2,2	1,45	3,3	1,4	6,6	2,0	9,0	0,63	58,0	1,72	21,9
	25—27	1,5	2,2	1,42	5,3	1,47	2,0	—	—	1,19	20,7	1,74	20,9
	45—47	1,5	2,18	—	—	1,49	0,6	—	—	1,17	22,0	1,86	14,6
56 Iron humic-peat soil	7—10	1,5	2,2	1,39	7,3	1,11	26,0	1,93	12,3	0,99	34,0	1,75	20,5
	25—27	1,5	2,18	1,43	4,7	1,41	6,0	2,04	6,4	0,76	49,3	1,80	17,4
	45—47	1,5	2,2	—	—	1,55	0	—	—	1,03	31,3	1,75	20,5
56a Iron humic-peat soil under cabbage	7—10	1,5	2,2	0,65	56,6	0,21	86,0	1,27	42,3	0	100	0,57	74,1
	25—27	1,5	2,2	1,10	26,6	0,69	54,0	1,23	44,1	0,17	88,7	0,51	76,8
	45—47	1,5	2,2	—	—	1,38	8,0	2,06	6,4	1,21	19,3	1,91	13,2

Note: Comma represents decimal point.

Lipomyces yeasts.

The assessment of nitrogen-fixing bacteria in the soils of Profiles 54, 56, and 58 under perennial grasses revealed the presence of casual organisms of the first phase of nitrification; bacteria of the second phase, however, were found only in fallow soil; the number of casual organisms of the first nitrification phase varied from 10^3 to 10^7, while the number of casual organisms of the second phase varied from 10^3 to 10^5 during a season.

Cellulose-decomposing bacteria were found to a depth of 30 cm. We discovered that, in addition to bacteria, fungi and actinomyces also participate in this process. Bacteria close to Cytophaga hutchinsoni, myxococci, and other myxobacteria were the most widespread bacteria in all the soils.

Intense decomposition of cellulose under anaerobic conditions, accompanied by the formation of hydrogen sulfide took place when the soils from Profiles 54 and 58 were inoculated. It was most intense when the upper soil layers were inoculated; we did not observe the development of anaerobic cellulose bacteria below a depth of 30 cm.

To determine the intensity of cellulose decomposition under natural conditions we experimented on three soil profiles: Profiles 56 and 58 under grasses and Profile 56a in an area where cabbage was grown, but removed before the experiments were started. Cellulose was added in the form of cotton cloth and filter paper (the latter was placed in the soil in caprone bags) to a depth of 7-10, 25-27, and 45-47 cm. The experiments were checked every month, they lasted 3 months.

As we can see from Table 3, cellulose decomposition was most intense in iron humic soil under row crops (Profile 56a), i.e., under good aeration conditions. As we have already reported in our previous investigations (13, 14, 15), the active microflora, studied by direct observation in the soil itself, is dynamic and varied. The composition of its microbial communities depends on the complex of conditions present in the soil at a given time.

The active microflora of the humic-peat soils studied was also varied and changed during the growing period. To show the nature of these changes, Tables 4 and 5 describe two soils differing greatly from each other: clay-peat soil (Profile 54) and iron calcareous humic-peat soil (Profile 58).

The active microflora of clay-peat soil (Profile 54) developed moderately in 1953, primarily in the upper soil layer (Table 4). Under the conditions prevailing in 1954 weak growth was observed in June. Intense bacterial development occurred throughout the profile to a depth of 70 cm in July and, especially, in August. All groups of microorganisms (Fig. 1-a) were represented in the composition of microbial communities, with a slight predominance of bacteria. Fungi developed sufficiently energetically, but they were mostly in a deformed state, expressed by bacuolization, barren, twisting, the autolysis of hypha, as well as their lysis, caused by bacteria (Fig. 2-a, -b, -c). Actinomyces developed during almost all periods of observation. Their development was especially intense in the upper soil layers. At certain periods they split and formed spores (Fig. 2-d). Bacteria were numerous, but the predominating forms were non-spore-forming bacteria: ovals of various sizes, coccus bacilli, myxobacteria, etc. Spore-forming bacteria, such as clostridial and plectridial forms, were found only during individual periods and in a small number. According to the composition of its active microflora, namely the abundant development of actinomyces and non-spore-forming bacteria, clay-peat soil comes close to mineral soils on watersheds.

According to the intensity and nature of its growth, the active microflora of iron humic-peat soil (Profile 56) is similar to the microflora of the clay-peat soil, but its most dense growth occurred to a depth of 30 cm. Fungi and actinomyces developed here intensely only during individual periods, for instance, in July and August, 1954. With the relatively low moisture (187%-139%) and high temperature (21°-18°C) of the soils, the fungi formed a mycelium net, but they were almost always subject to lysis by bacteria. Under favorable conditions, the development of actinomyces reached spore formation, while during other periods of observation they developed in the form of single hyphae without branching.

Bacteria were the basic microflora of this soil, represented by various non-spore-forming and spore-forming forms, clostridial and plectridial forms developing in great numbers among the latter.

The iron-calcareous humic-peat soil (Profile 58) differed from the clay-peat (Profile 54) and iron humic-peat soil (Profile 56) in that its active microflora was less fully developed primarily in the upper soil layer to a depth of 10 cm and reached a depth of 30 cm during individual periods only. But in certain cases, the active microflora of this soil was strongly depressed at all the depths investigated, in spite of favorable soil moisture and temperature conditions (Table 5, July 9-12 and July 19-26, 1955). Fungi were frequent in the composition of the active microflora in the upper soil layer, but they were even more depressed and more rapidly lysed by bacteria than in the foregoing soils. Actinomyces developed only in the form of single hypha during almost all the periods of investigation. The leading microorganisms were various spore-forming and non-spore-forming bacteria, whose composition and ratios changed during various periods, depending on soil conditions (Fig. 1-b).

The dominant group in the composition of the active microflora of all the soils under perennial grasses, was various spore-forming and non-spore-forming bacteria. In spite of the variety of bacterial forms, the most widespread and constant among them were common to all three soils. The most widespread forms among spore-forming bacteria were those resembling Clostridium pasteurianum, C. polymyza, C. butyricum, Bacillus tetani, B. pectinovorum, B. dissolvens, B. cellulosae

Table 4

Nature of the growth on glasses in clay-peat soil (Profile 54) under grasses

Date, temperature, moisture	Depth, cm	Growth intensity	Fungi	Actinomyces	Bacteria
July 26-30, 1953	5—10	Focal average	Moderate amount with deformed mycelium. Beginning of the formation of spores and oidium	Average amount, hypha beginning to branch	Average amount of coccus bacilli, accumulation of clostridium, medium and small ovals, a few forms similar to Bac. subtilis
Same	12—17	Intense	Many, formation of Mucor spores, part of the hypha are vacuolized and destroyed by bacteria	Many predominate in the form of micro-colonies and hypha nets, partly frag.	Coccus bacilli predominate, often located along fungus hypha
Same	22—29	Weak	Few, rare hypha	Few, single hypha, weakly branched	Single, average-size ovals
Same	45—55	Better than at a depth of 22-29 cm	Few, in the form of rare colonies	Single hypha in initial growth stages	Few, occur in foci: bacteria of the type of Bac. cellulosae hydrogenicus and Bac. cellulosae methanicus predominate, somewhat less small oval forms, partly with spores, and a few little rods
June 6-14, 1954 +11.2°	5—8	Weak focal	Few, in foci, the hypha are warped, lysed by bacteria. Single formation of multicellular spores	In individual mycelium foci	Few, exclusively non-spore forming bacteria in the form of single cells and small accumulations
+6.2°	35—40	Weak	Individual deformed hypha	Not found	
July 10-15 121—94%	5—10	Very intense	Many, autolysed and lysed by non-spore-forming bacillus	Many, forming a dense network in places, part is fragmented	Many non-spore-forming bacteria: small mycolythic rods and accumulations of small oval cells. Cytophaga in places

Table 4 continued

Date, temperature, moisture	Depth, cm	Growth intensity	Fungi	Actinomyces	Bacteria
147—135%	20—30	Focal average	Many, part of the hypha are empty, antagonistic phenomena are developed	Many, form spores	Many, non-spore-forming bacteria predominate – various small bacilli, small ovals, and more rarely cocci. There is less spore-forming bacteria – large and medium plectidial ovals of the type of Bac. cellulosae hydrogenicus, there are less clostridial ovals of the type of clostridium Pasteurianum, C. butyricum, and yeasts.
384%	40—45	Very weak	Individual hypha		Not found
August 10-17 17.8—20.2°, 114%	5—10	Very intense	Dominate Mycelium net, part of the hypha, lysed by bacteria	In individual foci, part is fragmented	Only non-spore-forming bacteria: small cocci and thin, slightly bent rods
+15.8—17.3° 254%	25—30	Same	Many, part is vacuolized	Many, forming a net in places	Many, non-spore-forming bacteria predominate: coccus bacilli, small, thin rods, there are less Azotobacter-like cells. Among the spore-forming bacteria there is Clostridium butyricum with sporegenic grains and short, thick rods of the type of Bac. megatherium
+13.4—12.8°	65—70	Average intensity	Average amount, occur in foci, lysed by bacteria in places	Few, occur in foci	Many, various spore-forming bacteria predominate; plectidial Bac. dissolvens B. Tetani, B. cellulosae hydrogenicus and clostridial Clostridium pasteurianum C. polymyxa, B. closteroides

Table 5

Nature of the growth on glasses in iron-calcareous humic-peat soil (Profile 58) under grasses

Date, temperature, moisture	Depth, cm	Growth intensity	Fungi	Actinomyces	Bacteria
June 6-14, 1954	5—10	Very intense	'Average amount. Vacuolization of hypha, "special branching," antagonism phenomena between bacteria and actinomyces in individual foci	Average amount in foci	Very few. Great accumulation of Cytophaga and Cellvibrio cells, thin rods and various cocci, including Azotobacter-like. Among the spore-forming bacteria there are large rods of the type of the vegetative stage of Clostridium, small and large ovals with spores. The vacuolization of the contents is characteristic
Same	20—30	Intense	Few, vacuolized mycelium	Very low	Many, spore-forming bacteria predominate. In composition the organisms resemble those described for a depth of 5-10 cm, the number of small rods and cocci has decreased shrp.
"	40—45	Weak	Few, hypha with vacuolized contents	Not found	
July 10-15 266—275%	5—10	Moderate, focal	Few, part of the hypha is well preserved, the rest is lysed	Few, in foci, single hypha	Many, non-spore-forming bac. predominate: various small rods, cocci, ovals, cellu. bac.: Cellvibrio and Cytophaga. Spore-forming bac. are of the type of the vegetative stage of Clostridium Bacillus longissimus, B. asterosporus and accumul. of oval spores. All the organisms are in microcolonies and accumula.
410%	20—30	Intense, focal	Average number, partly autolysed and lysed by bacteria	Single	Many, spore-forming bacteria predominate: large cells similar to B. megatherium, B. subtilis, and vegetative stages of Clostridium. Many spores of various sizes. Among the non-spore-forming bacteria—fields of large Azotobacter-like cells and thin rods. The autolysis of cells is characteristic

Table 5 continued

Date, temperature, moisture	Depth, cm	Growth intensity	Fungi	Actinomyces	Bacteria
551%	40—45	Weak	Few, hypha are autolysed	Not found	Few, scattered or in accumulations near pieces of organic matter, non-spore-forming rods are straight or bent like *Cellvibrio*
Aug. 11-17	5—10	Intense	Many, in the form of hypha nets, autolysed	Many, occur in focci forming a net, partly fragmented and break apart	Many. *Azotobacter*-like cells, coccus bacilla, thin double rods. Thin and thick rods among spore-forming bacteria
410%	25—30	Moderate, focal	Predominate. Hypha are partly deformed: autolysis	Not found	Few, plectridial and clostridial cells
298%	5—10	Very weak	Single hypha with vacuolyzed or uncolored contents	Not found	
416%	40—50 65—70	No growth			
+18.+14.6°, 217—268%	5—10	Weak	Few, the hypha are deformed and severely lysed by bacteria	Few, part of proactinomyces	Few, in foci. Among the spore-forming bacteria — ovals and cells of the type of *B. closteroides*, among non-spore-forming bacteria— coccus bacilli
+16.4° +14.8°, 223%	15—20	Same	Thin net of empty hypa	Not found	Single colonies of small rods
			Cell autolysis is characteristic for all organisms		
July 30—Aug. 3-6	7—12	Very intense	Many, form a net of partly deformed hypha, which are almost completely autolysed at the end of the experiment	Few	Many. In 3-day experiments the domination spore-forming bacteria are: plectidial, large rods, ovals. Tremendous amounts of coccus bacilli

Table 5 continued

Date, temperature, moisture	Depth, cm	Growth intensity	Fungi	Actinomyces	Bacteria
May 3-30, 1956 +1.4°, +4.6, +8,2°, 343—395%, Water at 15 cm depth	8—11	Intense, uneven	Not found		Many, scattered or in accumulations. Myxobacteria predominate, there are less small rods. There are less spore-forming bacteria: rods with oval and pointed ends, small drumsticks and single clostridial cells
June 2-8, 1956 +11°, +13.2°, +15.2° 281—300% 2. June water at 24 cm depth.	7—10	Intense	Single hypha, partly or completely empty, several are torn	Single very thin discontinuous hypha	Many, short, thread-like bacteria with a terminal spore, similar to *Bac. cellulosae hydrogenicus*, and myxobacteria-like cells predominate. Considerable amount of forms of the vegetative stage of *Clostridium*, quill-like, large bean-like cells, diplobacilli, small rods, plectidial and others. There are free spores and amoebae.
+7.8°, +10.8°, 339—500%	21—24	Moderate	Not found	Similar to the depth of 7-10 cm	Various thin and long forms with a terminal spore, small rods and ovals, and *Cellvibrio* cells
June 23-29	7—10	Moderate, focal	Many, hypha autolyse	Few	Small forms predominate: micrococci, coccus bacilli, rods and ovals; there is much less long rods. Cell autolysis
+14.6° 345—312%	18—21	Similar to the depth of 7-10 cm	Not many, severely deformed	Very few	Cocci and coccus bacilli
June 23-July 3 +11.2°, +12.3°, 568%	35—40	Weak	There is a large number of empty hypha in the foci	Few	Detritus as a result of cell autolysis

Table 5 continued

Date, temperature, moisture	Depth, cm	Growth intensity	Fungi	Actinomyces	Bacteria
Aug. 16-25 +14°, +13.4, +17.2°, 200—248%	5—10	Intense, focal	Many in individual foci, hypha are deformed	Not found	Many in individual foci. Coccus bacilli, clostridial forms, there is less large ovals and rods
+13.3°, 12.8°, +14.2°, 330—299%	25—30	Weak	Few, pieces of deformed hypha	Very few	Few. Colonies and accumulations of ovals and large rods. Part of the cells is autolysed
+11.8°, +12.5°, 533—642%	45—50	Weak, focal	Not found	Not found	Accumulations of *Cytophaga*, *Cellvibrio* microbacteria, anaerobic cellulose bacteria and clostridial bacteria in ind. foci

hydrogenicus, *B. closteroides*, and *B. asterosporus* (Fig. 3-a, -b, -c). Such forms of bacteria as *B. mycoides*, *B. subtilis*, and *B. megatherium* were found only during individual periods.

The most widespread among non-spore-forming bacteria were various forms of myxobacteria, such as *Cytophaga*, *Cellvibrio*, ovals of various sizes, coccus bacilli, cylindrical rods, myxobacteria, and *Azotobacter*-like cells (Fig. 2-b, -e, -f, Fig. 3-d, -e, -f). The autolysis of bacterial cells was often observed in these soils.

The active microflora of iron humic-peat soil (Profile 61) and iron-calcareous soil (Profile 58a) in fallow differed from the active microflora of the same soils under grasses in that their bacterial population was denser during all periods of observation (Fig. 1-c).

Fungi and actinomyces developed almost in the same manner as in soils under grasses. The main composition of bacterial flora was also similar to that described earlier; the content of various forms of myxobacteria in the composition of the complex of non-spore-forming bacteria increased particularly and many different thin, thread-like forms appeared. A large number of *Azotobacter*-like cells appeared in the iron-calcareous soil (Fig. 4-a, -b, -c, -d, -e, -f).

On the basis of the investigations on the potential microflora of cultivated peat soils we could assume that the decomposition and mineralization of plant residues in them must proceed rather intensely and thus ensure the necessary elements of mineral nutrition to the plants. However, the systematic study of the active flora showed that there is an inconsistency between the potential and active microflora in iron humic-peat soils and, especially in iron-calcareous soils. Because of low temperatures and frequent excessive moisture, the microflora of humic-peat soils is active for a relatively short period. When changing into the active state, the organisms develop slowly and their metabolism is low, which results in the slowing down of biochemical processes. This is substantiated by observations on the intensity of cellulose decomposition under natural conditions in iron and iron-calcareous soils.

Iron-calcareous soil is characterized by the low intensity of cellulose decomposition. The decomposition of complex nitrogen-containing substances is as slow here. In spite of the high nitrogen content (1.25%), the amount of its mineral forms is small even under favorable temperature, moisture, and aeration conditions, which indicates that most of the organic nitrogen compounds in the soil are not readily available to microorganisms. Thus, the content of ammonia in iron-calcareous soil in the fallow plot did not exceed 8.1 mg/100 g of absolutely dry soil, while the content of nitrates did not exceed 13.9 mg.

One of the reasons for the weak mineralization of nitrogen is the deficiency of readily available forms of carbon. The slow decomposition of complex carbon-containing substances,

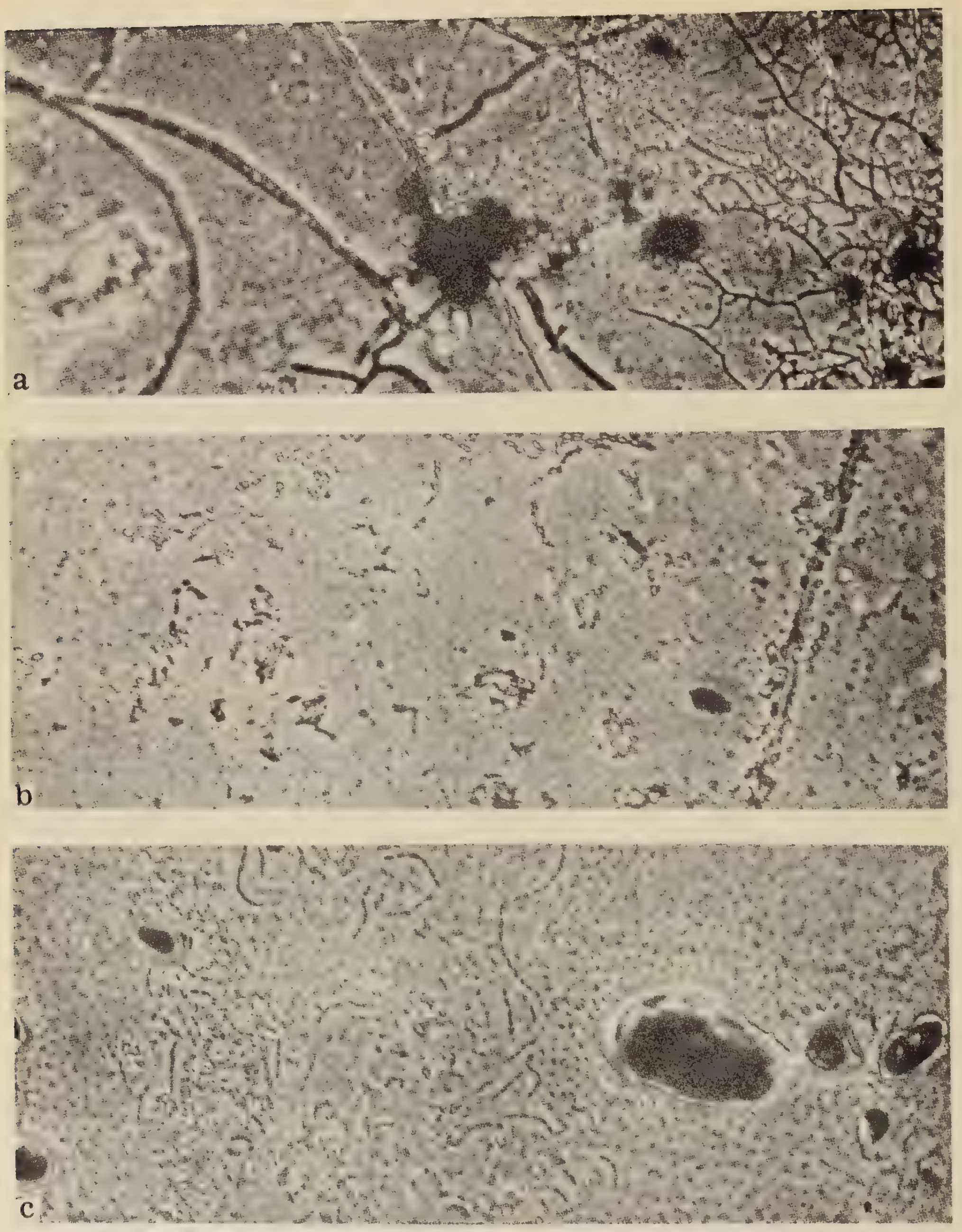

Fig. 1. - General view of the growth on glasses in the soil.

a - in clay-peat soil, Profile 54; b - in iron-calcareous humic-peat soil, Profile 58; c - in iron-calcareous humic-peat soil, Profile 58a. Magnified 400 times.

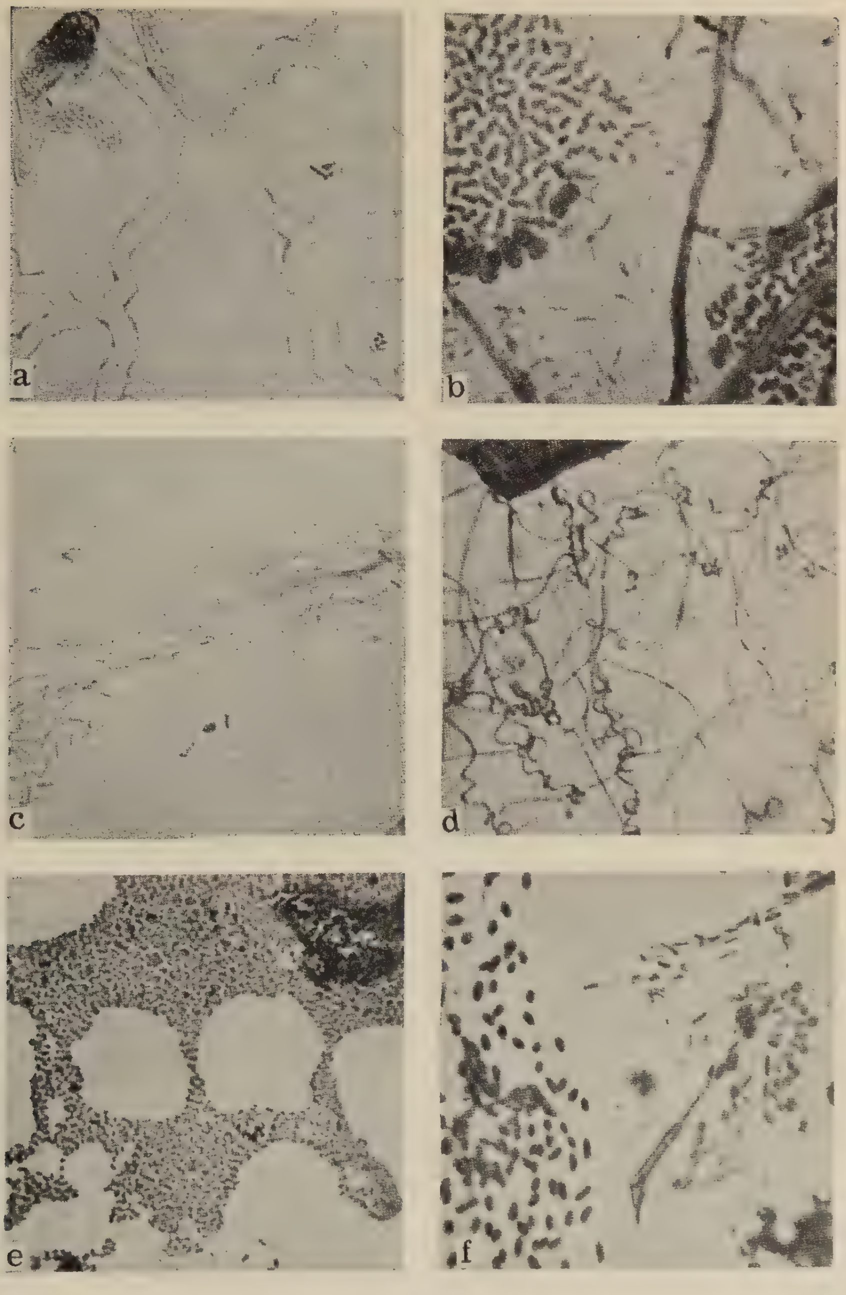

Fig. 2. - Characteristic forms of microorganisms.

a - fungus hypha, partly empty, partly with granulated contents; b - fungus hypha and ovals of various sizes; c - destruction of fungus hypha by thin rods; d - actinomyces, formation of spirals and fragmentation; e - coccus bacilli; f - two types of ovals. Magnified 1000 times.

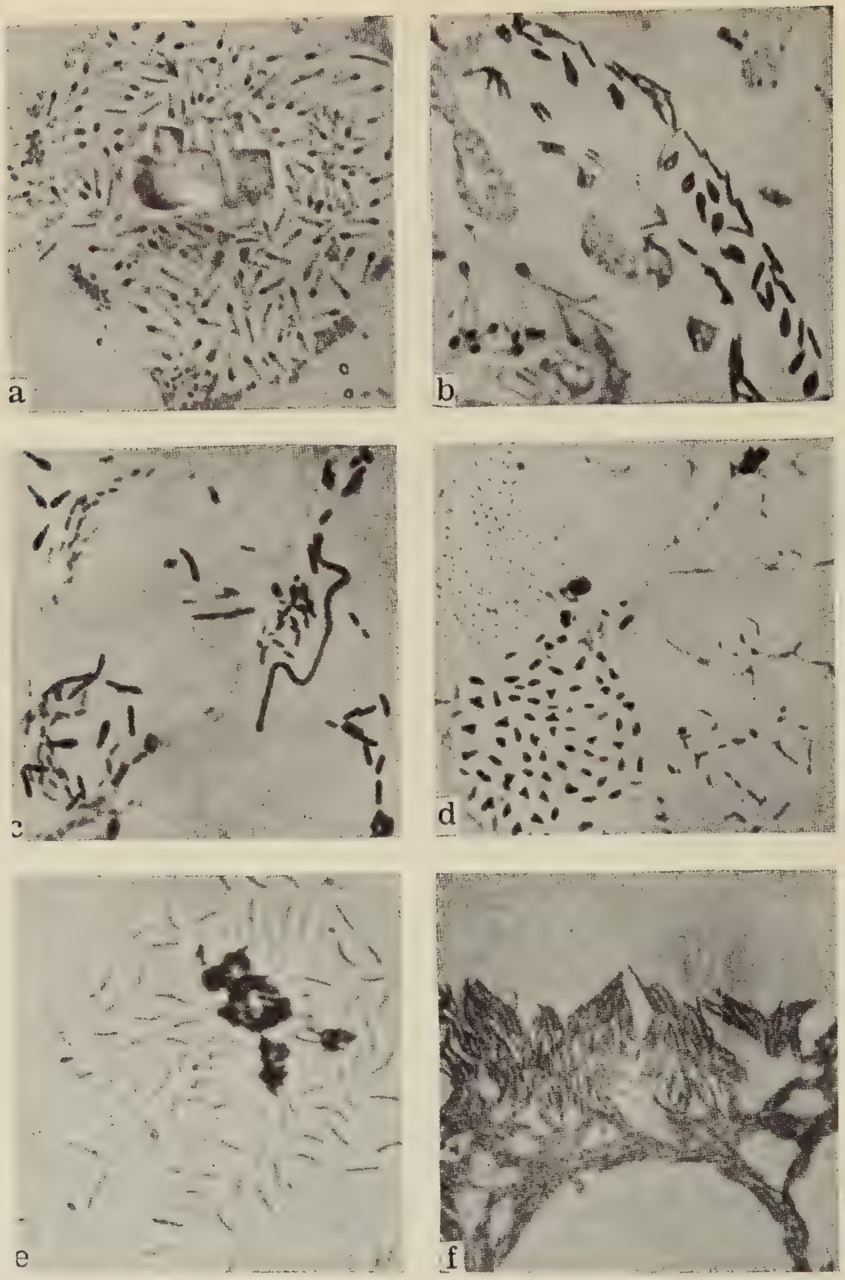

Fig. 3. - Characteristic forms of microorganisms.

a,b,c - clostridial and plectridial forms; d - mycobacteria; e,f - mycobacteria. Magnified 1000 times.

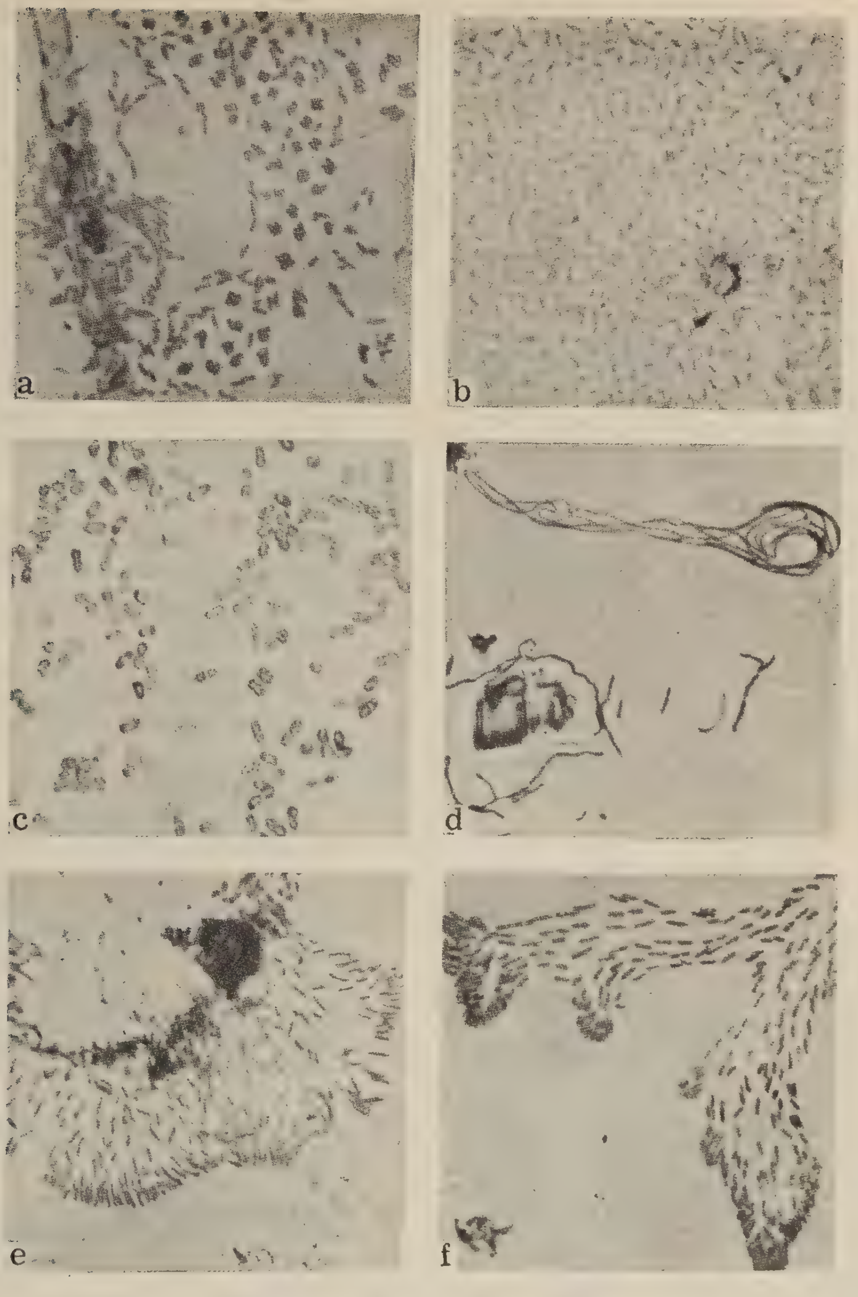

Fig. 4 - Forms characteristic of fallow.

a,b - various small rods; c - *Azotobacter*-like cells; d - thread-like forms; e,f - characteristic microcolonies. Magnified 1000 times.

Table 6

Ammonia and nitrate content in the fallow plot of iron-calcareous soil, mg/100 g of absolutely dry soil

Ammonia						Nitrates					
June 6	June 11	June 21	July 11	July 25	Aug. 6	June 6	June 11	June 21	July 11	July 25	Aug. 24
8.1	1.8	5.6	Traces			None	Traces	9.6	8.7	13.9	None

such as cellulose, limits the supply of carbon sources available to microorganisms in the soil. But since during decomposition of complex organic nitrogen compounds many microorganisms cannot use the carbon from these compounds, their mineralization is slowed down, which results in a deficiency of mineral forms of nitrogen in humic-peat soils.

The reason for the discrepancy between potential and active microflora is deficiency of carbon and nitrogen forms available to the microorganisms. Therefore, a considerable part of the microorganisms in this soil remains in a potential state most of the time.

It follows from the foregoing that the large amount of nutrients present in peat soils can be mobilized by increasing the biological activity of these soils, i. e., creating possibilities for the development of active microflora. This can be achieved by regulating the water regime and aeration of soils and by reducing the period during which they are under grass.

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INFLUENCE OF THE AGRICULTURAL UTILIZATION OF LOWLAND BOGS ON THE PROPERTIES OF PEAT SOILS UNDER CONDITIONS OF THE ESTONIAN SSR

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The wide reclamation of bogs began in Estonia as early as at the end of the last century. However, the physicochemical properties of peat soils and their change during the cultivation of the bogs have not been studied sufficiently. We will discuss these problems below.

Part of the material presented was obtained at the so-called first experimental plot of the Tooma Experiment Station. The experiment was started in 1911. Peat in the experimental plot consists of hypnum, reed, and sedge residues, and the degree of its decomposition is approximately 15%-20%. We will call this peat slightly-decomposed lowland peat. It is from 1.7 to 6.0 m thick.

The other part of the material was obtained from a plot in a lowland bog, established in 1913-1914. Woody residues predominate in this peat. The degree of decomposition of the upper 40 cm of this peat is 35%, and that of the lower layers is 40%-45%. We will call this well-decomposed peat. Its thickness varies from 1.5-3.0 m. The bog was drained by means of tile drains. The drains were placed at a depth from 120-130 cm. This drainage has been partly preserved to our day. Pole drains were also used for comparison.

After drainage, a vetch-oat mixture was sown on both plots as a preliminary crop. Potassium and phosphorous fertilizers were added in triple-applications in the first year of utilization, part of which remained in the soil as a reserve. After the preliminary crops, perennial grasses were sown in the experimental plots. These plots were used later as hayfields.

Influence of the Agricultural Utilization of Bogs on the Physical Properties of Peat Soils

After drainage peat settles and compacts, i.e., its bulk density increases. This increase is uneven and corresponds to the settling of the bog. The data in Table 1 shows that the bulk density of the slightly-decomposed peat increased 21% within a year after drainage. Later, the intensity of the increase in bulk density diminished. The total pore volume of the peat soil changed relatively little, which is attributable to its relatively low bulk density (Table 1). The small change in general porosity during the settling of the peat bed does not reflect those changes which take place in the properties of the pores. As we can see from Table 2, the volume of the large pores decreased several fold as a result of settling, especially in the surface layers.

Active pores[1] comprise 63.1% of the volume at a depth of 25-30 cm in natural slightly decomposed peat soils, while non-capillary pores comprise 6%. After 47 years of use these pores occupy 30% of the total volume of such a peat soil at a depth of 25-30 cm. The percentage of active pores at a depth of 70-75 cm also decreases with time. Consequently, the settling of peat takes place primarily as a result of the decrease in volume of the large pores. Since the total pore volume decreases only little as a result of settling, the volume of pores with a lesser effective diameter increases correspondingly (Table 2).

A decrease in the effective diameter of pores results in a decrease in the water permeability of peat, and drainage conditions degenerate. The foregoing problem was studied in detail by Tomberg (5), a member of the melioration section of the Estonian Scientific-Research Institute of Agriculture and Melioration.

The field moisture capacity[2] of the drained layer of peat increases and the air content in the soil increases, as compared to the first years after drainage, as a result of the increase of the group of pores with a small effective diameter when the soils are covered for a long time with perennial grasses. The

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[1] Pores with an effective diameter of >0.003 mm.

[2] The field moisture capacity was determined in spring when drainage discharge and evaporation from the soil are at a minimum. In summer, field moisture capacity was verified by the method of S.I. Dolgov. The effective diameter of the pores, corresponding to field moisture capacity, was determined by means of a capillarimeter.

Table 1

Change in the bulk density and pore volume of slightly-decomposed peat soil after drainage

Year of sampling	1948[a]	1950	1955
Bulk density, g/cm³ of absolutely dry soil	0,107	0,130	0,142
Change in bulk density, %	100	121	133
Pore volume, %	93	92	91
Change in pore volume, %	100	99	98

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[a] Year when drains were installed.

Note: Comma represents decimal point.

Table 2

Influence of the agricultural utilization of slightly-decomposed peat soils on the properties of their pores

Soil characteristics	Depth, cm	Non-capillary porosity, %	Distribution of active pores by effective diameter (mm), % of soil volume								Total porosity, %
			>0,2	0,2—0,1	0,1—0,05	0,05—0,02	0,02—0,01	0,01—0,005	0,005—0,004	Total	
Natural slightly-decomposed peat soil	25—30	6	15	18	18	9	1,2	1,1	0,8	63,1	92
	70—75	6	16	17	18	9	5,6	2	1,2	68,8	93
Slightly-decomposed peat soil after 47 years of use	25—30	1	3,9	3,4	7,4	8,9	2,6	2,0	1,6	29,8	90
	70—75	2	8,3	7,0	13,0	14,3	5,3	4,5	3,5	55,9	91

Note: Comma represents decimal point.

field moisture capacity of slightly-decomposed peat soils is determined by pores with effective diameters of <0.02 mm (3). The field moisture capacity of slightly-decomposed peat soils would have only been about 26% of the soil volume and 66% of the pores would have been filled with air (according to Table 2) if soil compaction did not follow drainage.

After 47 years of use under perennial grasses, the field moisture capacity of the same soil was 65% at a depth of 25-30 cm and 46% at a depth of 70-75 cm. Thus, the capacity of peat soil to release water decreased approximately 2-2.5 times during the foregoing period. The air content (at field moisture capacity) at a depth of 25-30 cm decreased to about 25%.

An increase in the number of small pores causes an increase in the height of the capillary rise,[3] and an inversely proportional decrease in its rate. Consequently, capillary rise has no effect on the water regime of the plowed layer in summer, when the ground-water level is below 80 cm. Judging from experimental data, the height of intense capillary rise is 15-25 cm in natural slightly-decomposed peat. After peat soils are utilized for a long time, the capillary rise reaches 35-50 cm from the ground-water level.

There are small pores with an effective diameter of more than 0.01-0.02 mm in well-decomposed peat (Table 3). There are also small non-capillary pores. Therefore, in well-decomposed peat soils there are no such large changes in properties affecting the relation between water and air, as are observed in slightly-decomposed peat soils.

Influence of Agricultural Utilization on the Decomposition of Peat Soils

As we can see from the foregoing, the change in the physical properties of peat soils after reclamation is greatest in the upper layers. These changes depend not only on the processes

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[3] Capillary rise was determined from the volumetric water content of the soil and the approximate rate of movement of soil water, by means of gypsum blocks.

Table 3

Influence of agricultural utilization of well-decomposed peat soils on their porosity

Soil characteristics	Depth, cm	Non-capillary porosity, %	Distribution of active pores by effective diameter (mm), % of soil volume								Total porosity, %
			0,2	0,2–0,1	0,1–0,05	0,05–0,02	0,02 0,01	0,01–0,005	0,005–0,004	Total	
Natural well-decomposed peat soil	25—30	1	2	1,0	2,5	7,3	4,8	10	3	31,2	89
	70—75	0	1	2	2,7	9	3,7	9	4	31,4	89
Well-decomposed peat soil after 47 years of use	25—30	1	1,8	1,6	2,2	6,3	4,2	10,6	3,8	30,5	88
	70—75	0	1,2	1,8	2,2	9,3	3,2	8,6	4,1	30,4	88

Note: Comma represents decimal point.

of settling, but also on certain, more complicated biological processes, associated with the agricultural practices used. The organic matter decomposes (mineralizes) under their influence and the content of ash and ash elements in the soil increases. As a result of the mineralization of organic matter, the plowed layers of peat soil compact, their bulk density and degree of peat decomposition increase, and its upper layer settles.

To determine the intensity of mineralization of peat soils under the influence of their agricultural use, the peat from the plots described earlier was analyzed again in 1953[4] (the first analyses were made in 1910) (6). As we can see from Table 4, slightly-decomposed peat soil contained considerably less ash and ash elements than the well-decomposed peat soil. The content of mineral substances increased considerably in both peat soils as a result of reclamation. The content of ash and lime (CaO) increased most intensely in the slightly-decomposed peat soil. Consequently, the process of mineralization of organic matter was much more intense in this soil.

It is interesting to note that in spite of the accelerated mineralization of slightly-decomposed peat soils, the content of mineral substances in them did not reach their level in well-decomposed peat soils in 43 years (Table 5).

The enrichment of the soil with nitrogen proceeded differently. The well-decomposed peat soil contained somewhat more nitrogen than the slightly decomposed peat soil at a depth from 0-20 cm and somewhat less than the latter at a depth of 40 cm in 1910 (Table 4). The nitrogen content in both soils increased insignificantly as a result of decomposition. Apparently, the organic matter in the well-decomposed peat soil, rich in humus, was slightly subject to decomposition. Because of the greater bulk density and the high degree of mineralization, the amount of nitrogen was higher in the well-decomposed peat soil than in the slightly-decomposed peat soil, and its nitrogen was more mobile.

In the slightly-decomposed peat soil decomposition is apparently more intense because of its higher content of cellulose and other compounds, which are easily subject to biological decomposition. The greatest part of the nitrogen released during mineralization is used during intense microbiological processes and is retained in the biological cycle of the soil, while a small part of it is lost in the gas form. If no nitrogen were lost during mineralization, its content in the soil would increase in the same manner as the amount of ash elements increases.

A comparison of the results of chemical analyses with the results of studies at the Minsk experiment station (1) showed that when peat soils are reclaimed, the amount of nitrogen in them does not increase, but may decrease. The calcium content increases, according to the data of the Minsk experiment bog station, as shown in Table 4.

The content of nitrogen compounds does not increase in the soils of the Minsk experiment bog station apparently because grain and row crops are primarily grown on reclaimed bogs. The peat soils of the Tooma Experiment Station are used for arable hay fields. This type of utilization does not permit the intense cultivation of peat soils, as a result of which the decomposition of organic

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[4] The chemical composition of peat soils (at the Experiment Station Tooma), which were reclaimed from 1911-1914 was analyzed in 1953 in the laboratory of the former Institute of Melioration and Reclamation of Drained Lands of the Academy of Sciences of the Estonian SSR. These data are used in the present paper.

Table 4

Influence of agricultural utilization of peat soils on their properties (Tooma Experiment Station)

Depth, cm	Year of sampling	Degree of decomposition, %	Bulk density		In % of absolutely dry soil							
			g/cm³	%[a]	CaO	%	N	%	R_2O_3+	%	Ash	%
			Slightly-decomposed peat soil									
0—20	1910	15—20	0,138	—	2,44	—	2,87	—	0,63	—	6,07	—
0—20	1953	30—35	0,157	14	4,44	82	3,31	15	1,67	167	10,9	79
20—40	1910	15—20	0,123	—	2,28	—	2,54	—	0,55	—	4,46	—
20—40	1953	25—30	0,140	13	3,85	69	2,82	11	0,96	74	8,08	81
40—60	1953	20—25	0,131	10	—	—	—	—	—	—	—	—
			Well-decomposed peat soil									
0—20	1910	25—30	0,148	—	4,70	—	3,0	—	0,65	—	8,58	—
0—20	1953	45—50	0,187	26	5,54	18	3,46	15	1,54	137	10,2	19
20—40	1910	30—35	0,179	—	3,09	—	2,47	—	0,76	—	8,56	
20—40	1953	45—50	0,182	2	6,11	98	3,14	27	1,05	38	9,32	9
40—60	1953	45—50	0,180	2	—	—	—	—	—	—	—	—

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[a] Increments

Note: Comma represents decimal point.

Table 5

Influence of cultivation on the mineralization of peat soils from 1910-1953

Indices	Slightly-decomposed			Well-decomposed		
	CaO	N	R_2O_3	CaO	N	R_2O_3
	cntr/ha					
Content in the peat layer from 0-40 cm in 1910	122,7	140,4	30,7	255,0	179,0	49,0
Content in the peat layer from 0-40 cm in 1953	245,1	183,5	77,5	430,6	244,0	95,0
Expected content in 1953[a]	—	249	—	—	255	—
Increase in the content of substances	122,4	43,1	46,8	175,6	65,0	46,0
Including:						
that from decrease in pore volume	17,0	19,6	4,3	32,8	23,0	6,0
that from mineralization	105,4	23,5	42,5	142,8	42,0	40,0
Added by fertilizers	—	—	—	—	—	—
Removed by crops	12,5	25,4	0	16,7	33,5	0
Total content of substances accumulated as a result of peat mineralization	117,9	48,9	42,5	159,5	75,5	40,0
Amount used by the peat soil, cntr/ha	4983	—	7129	4067	—	5355
Mineralized peat layer, cm/ha in 43 years	38	—	52	24	—	31
" " " in 1 year	0,88	—	1,2	0,5	—	0,7

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[a] Calculated from the amount of peat soil used $\frac{4983 \times 2.7\ (N\ \%)}{100}$ + 140.4—25.4=249 cntr (N).

Note: Comma represents decimal point.

matter is slow and under the influence of other biological processes than in soils on which grain crops are grown. In addition, the Tooma Experiment Station is much farther north than the Minsk bog station, which is reflected in the temperature regime during the growing period, on which the intensity of decomposition of organic matter depends greatly.

As we know, plants take up primarily the end products of peat soil mineralization. Since no nitrogen fertilizers are generally used on arable meadows on lowland bogs, the growth intensity of perennial grasses depends primarily on the amount of available nitrogen compounds forming in peat soil. Consequently, the nature of peat decomposition is reflected in the grass yield and its chemical composition. To determine the nature of peat decomposition we tried to compile an approximate balance of peat soil decomposition. The balance is approximate, since we do not know to what degree the ash elements are leached from the plowed layer of the soil and supplied to it by ground water. It must be noted that the CaO content in the ground water of a non-reclaimed bog, adjoining the experimental plots, was 60-80 mg/liter. This bog is in the process of becoming an upland bog. The chemical properties of the peat soils in the non-reclaimed bog are close to those of the soils analyzed in 1910.

It is interesting to note that the CaO content in the drainage water of the experimental plot also varies from 70-85 mg/liter. If the drains are located at the mineral bottom of the bog or 10-20 cm higher, the calcium content of the water increases to 120 mg/liter (CaO). Only traces of iron are found (the average annual drainage discharge amounts to about 200 mm/ha). Judging from the data presented, the loss of ash elements from the plowed layer by leaching is insignificant. The most mobile is calcium, since it accumulated in the soil less than R_2O_3 (Table 5) in 43 years. Since the experimental plots are located on a very thick peat bed, there is apparently little enrichment of the plowed soil layer from ground water. Even though the data on the nature of mobile calcium and R_2O_3 compounds in the drained peat soil are indirect, they still can be used to construct an approximate balance of nutrients in the plowed layer of the soil.

The chemical composition of hay from the arable meadow of the Tooma Experiment Station is the following: 4.7% ash, 0.65% CaO, 0.5% P_2O_5, and 1.3% N. The average yield of absolutely dry hay on the slightly-decomposed peat soils is 45 cntr/ha, while on the well-decomposed peat soils it is not less than 60 cntr/ha. Thus, 29 kg of CaO, 31 kg of P_2O_5, and 59 kg of nitrogen per hectare are removed annually with the crop from slightly-decomposed peat soil. The hay yield removes 260 kg of ash, 39 kg of CaO, 42 kg of P_2O_5, and 78 kg of nitrogen per hectare annually from the well-decomposed peat soil.

As we can see from Table 5, a considerable part of the nutrients contained in 1910 has been removed in 43 years from the slightly-decomposed peat soil. The amount of CaO and R_2O_3 in the peat layer from 0-40 cm increased more than twice during the period from 1910-1953. Nitrogen is again an exception. Its increase during the observation period was considerably less than that of ash elements. If during the decomposition of organic matter nitrogen compounds would accumulate in the same manner as the ash elements, then there would be not less than 249 cntr/ha nitrogen in the layer from 0-40 cm instead of 183.5 cntr/ha by 1953. Consequently, not less than 66 cntr/ha of nitrogen disappeared from the 0- to 40-cm layer of slightly-decomposed peat soil in 43 years (not counting the amount of nitrogen removed by the crop), i. e., almost three times more than was removed during this period by the crop. Since the grass yield on slightly decomposed peat soils, against a background of phosphorous-potassium and copper fertilizers is relatively low, we can say that the foregoing amount of nitrogen disappeared from the soil in a form unavailable to plants. From the foregoing it follows that little nitrogen compounds form during the mineralization of slightly-decomposed peat soil, which could be taken up by plants. As mentioned earlier, nitrogen losses during mineralization are determined by the formation of such compounds which volatilize in the gas form (denitrification, etc.), and also by the leaching of very mobile organic nitrogen compounds.

An unfavorable consequence of the mineralization of slightly-decomposed peat soil is the increase of the amount of iron and aluminum compounds (R_2O_3). The mobility of phosphorous compounds decreases under their influence and the soil reaction becomes less favorable.

The accumulation of ash elements is less intense in the well-decomposed peat soil than in the slightly-decomposed peat soil, because of their intensive uptake by perennial grasses (Table 5). The amount of nitrogen in the well-decomposed peat soil increases much faster thereby. Thus, 42 cntr/ha of nitrogen accumulated (in the layer from 0-40 cm) in 43 years in the well-decomposed peat soil as a result of its mineralization, while only 23.5 cntr/ha accumulated in the slightly decomposed peat soil. The hay yield was 15 cntr/ha higher on the well-decomposed peat soil than on the slightly-decomposed soil, and consequently the accumulation of nitrogen compounds available to plants was also considerably more intensive in the former.

It is clear from the foregoing that the nitrogen losses resulting from mineralization are considerably less in the well-decomposed peat soil than in the slightly-decomposed soil (Table 5). The same can be said of the rate of accumulation of iron and aluminum compounds. A high lime content apparently affects the intensity of nitrification, the reaction of the soil, and aeration, and this is the cause of the high effective fertility of well-decomposed peat soils.

As we can see from Table 5, the reclaimed well-decomposed peat soils became rich in ash elements and nitrogen not only as a result of decomposition, but also because of the compaction of the soil at the expense of the larger pores. The influence of the last factor on the increase of ash elements is relatively small as compared to the increase in ash elements as a result of mineralization. The increase in nitrogen content as a result of mineralization proved to be twice that as a result of the decrease in pore size. In the slightly-decomposed peat soil, the increase in nitrogen content as a result of mineralization exceeded that from the decrease in pore size only by 3 cntr/ha.

Judging by the ash content, 5000-7000 cntr/ha of slightly-decomposed and 4000-5300 cntr/ha of well-decomposed peat mineralized in 43 years, which corresponds to a peat layer 37-52 cm and 24-31 cm thick, respectively.

It follows from the foregoing material that the properties of slightly-decomposed peat soil change more rapidly under the influence of agricultural utilization than those of well-decomposed peat soil. The fertility of slightly-decomposed peat soil increases more slowly than that of well-decomposed peat soil. The reason for this is primarily the deficient nitrogen regime for cultivated plants. Perennial grasses suffer from a nitrogen deficiency and give low yields against the background of phosphorous-potassium fertilizers. It is interesting to note that relatively high hay yields were obtained on slightly-decomposed peat soils during the first 2-3 years after the perennial grasses were sown. Two to three years later the hay yield decreased by 25-30 cntr/ha. This shows that the necessary amount of nitrogen compounds, available to plants, does not form during mineralization. Moreover, there is a possibility for its unproductive losses.

In order to utilize slightly-decomposed peat soils more effectively perennial grasses should not be grown on them for too long a period of time. Clover must predominate in the composition of the grasses (4). It is recommended that perennial grasses be alternated with field crops (during 1-2 years). This would allow the more intense cultivation of the soils, which in turn would increase the accumulation of nitrogen compounds available to plants. This would lead to higher yields and to the more full utilization of nitrogen compounds which are released during the mineralization of the soil.

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UPTAKE OF MINERAL ELEMENTS AND NITROGEN FROM THE SOIL BY PLANTS IN THE FORESTS OF THE KOLA PENINSULA

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The biological cycle of substances consists of two opposed processes: the uptake of mineral elements from the soil by plants during their growth, and the return of these elements to the soil with the litter, root secretions, and dead portions of plants. By taking up chemical elements selectively from the soil, vegetation promotes the redistribution of mineral elements along the soil profile.

The present paper examines the problems of the uptake of mineral elements by plants under northern taiga conditions.[1] The northern taiga is characterized by: sparse tree canopy, low site quality, comparatively low total wood production, and an insignificant development of grass vegetation. The strong development of shrubs and of the lichen-moss cover in thinned and low forests determines the peculiar nature of the biological cycle of elements and, in particular, the qualitative and quantitative uptake of nitrogen and ash elements by plants.

The investigations were made in spruce and green-moss pine forests, which are widespread in the plain part of the Kola peninsula. Table 1 gives a brief evaluation of the forests studied.

As a result of the mixed age of the forests and the presence of associated species, we took several model trees in order to assess the wood story according to the method used by Remezov and his collaborators (3). The model trees (Table 2) were selected in such a manner that they would characterize every degree of thickness. To determine the total mass of the tree canopy from the weighed data obtained for the model trees, we draw curves of the change in trunk mass, branch mass, and foliage, depending on diameter. The tree masses, calculated graphically by degrees of thickness, were then summed. The same calculations were made for the associated species. The mass canopy of shrubs and moss was determined by the usual method for areas of 1 m^2 and repeated 10 times.

We could not determine the root mass for each tree species separately. Therefore, we limited ourselves to the determination of the entire root mass in each soil horizon for areas 1 m^2, which we then converted into hectares. This was repeated 5 times. The root mass of shrubs was determined directly for each shrub species by digging up the roots of individual shrubs. The weight of the shrub roots was then subtracted from the total mass of roots in the A_0 horizon.

Because we could not determine the root mass of individual trees, we used a somewhat conditional method of calculation and distributed the total mass of tree roots proportional to the trunk mass of individual species. A quantitative characterization of the wood story is given in Table 3. The assessment of the vegetative mass together with the ash composition of individual plant species permits the quantitative characterization of the uptake of mineral elements by the plants.

The ash composition of the vegetation of the Kola Peninsula has been studied little. Kursanov and D'yachkova (6) indicate that the ash of certain species of lichens in the Kola Peninsula contains up to 84% silicic acid (7). Levina described the total ash composition of all the shrubs and lichen-moss cover in two forest types. As far as we know, there is no information on the ash composition of trees in the Kola Peninsula in the literature. Table 4 gives data on the content of nitrogen and ash elements in the needles, leaves, branches, and trunks of various tree species in the forests studied.[2]

The data obtained almost completely agree with the pattern of distribution and the amount of mineral elements in various parts of trees, noted repeatedly in the literature (1, 8, etc.). Thus, leaves and needles are richest in all elements; tree trunks contain the least amount of nitrogen and ash elements. However, the trees of the Kola Peninsula differ from the

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[1] The article gives part of the data of a study of the cycle of nitrogen and ash elements under conditions prevailing in the Murmansk Oblast'. The work was done under the supervision of Prof. P. G. Aderikhin.

[2] The ash composition of shrubs (by species) and of the lichen-moss and grass cover is considered in another paper, which is going to be published in the collection of works by the Polar-Alpine Botanical Garden, entitled "Problems of Botany and Soil Science."

Table 1

Forest characteristics

Forest type	Site quality	Age	Density	Average height, m	Average diam. at a height of 1.3 m cm	Cross-sectional area, m^2	Composition
Whortleberry-spruce	Va	VI	0.5	10.9	14.9	11.92	7 E2 B1C
Blueberry-pine	V	V	0.6	7.8	12.1	16.49	6C 3B1 (I+E)

Table 2

Weight of model trees, kg of dry substance

Whortleberry-spruce					Blueberry-pine				
Tree species	$D_{1.3}$	Trunk	Branches	Needles (leaves)	Tree species	$D_{1.3}$	Trunk	Branches	Needles (leaves)
Spruce	6,0	6,53	0,75	0,20	Pine	6,0	4,98	0,83	0,51
"	8,0	11,08	1,81	1,03	"	8,0	10,91	2,06	0,80
"	11,0	16,32	3,98	2,31	"	10,0	23,21	4,10	1,45
"	12,5	22,93	5,04	3,19	"	12,0	29,90	6,60	2,09
"	14,0	27,86	5,01	3,92	"	14,0	44,10	10,81	3,64
"	17,0	44,98	8,10	6,30	"	16,0	56,04	11,50	5,93
"	18,0	55,0	11,05	7,40	"	18,0	79,8	12,04	7,70
"	20,5	73,10	14,08	9,41	"	20,0	99,9	17,1	9,20
"	22,0	90,5	19,15	10,50	"	24,0	158,8	47,0	11,63
"	24,0	106,21	20,32	12,10	Birch	6,0	2,11	0,32	0,11
"	26,0	142,0	29,0	13,30	"	8,0	4,03	0,54	0,31
"	28,0	185,0	33,0	14,1	"	11,0	16,08	2,76	1,02
"	30,0	240,1	38,15	15,6	"	12,5	30,11	3,96	1,24
Birch	8,0	3,29	0,42	0,22	"	14,0	38,80	4,50	1,48
"	10,5	18,44	2,92	0,82	"	16,0	54,10	5,05	1,58
"	12,0	23,50	3,15	1,02	"	18,0	65,60	5,10	1,73
"	13,5	36,09	4,01	1,36	"	20,0	93,80	5,51	1,80
"	16,0	49,00	5,60	1,57	Willow	6,0	4,13	0,48	0,96
"	18,0	63,2	6,03	2,31	"	8,0	10,61	1,30	1,03
"	20,0	81,36	6,50	2,53	"	10,0	19,04	2,49	1,84
Willow	12	22,3	6,1	2,80	Pine, undergrth.	—	1,01	0,21	0,09
"	28	268,4	62,8	24,94	Same, birch	—	1,12	0,13	0,05
"	38	394,8	93,6	41,19	Same, willow	—	1,86	0,24	0,10
"	—	—	—	—	Same, spruce	—	2,52	0,39	0,23

Note: Comma represents decimal point.

trees of more southern regions in that they contain less ash and somewhat more manganese in the ash, which accumulates in relatively large amounts in spruce and pine needles.

Certain differences in ash composition were found between the same plant species in the whortleberry-spruce forest and the blueberry-pine forest. Thus, the ash of plants in the former forest generally contained a high amount of silicic acid, aluminum, and sodium, while the latter contained more nitrogen and partly phosphorus and sulfur.

We calculated the accumulation of nitrogen and ash elements in the mass of vegetation growing in an area of 1 ha in the spruce and green-moss pine forests on the basis of data on their content in the organic substance of trees (Table 5). The total accumulation of mineral elements per unit area is considerably higher in the blueberry-pine forest than in the whortleberry-spruce forest. An especially large amount of calcium, magnesium, potassium, manganese, and nitrogen accumulates in the vegetation of the blueberry-pine forest. But if we should compare this accumulation with the amount of mineral elements in the

Table 3

Organic mass of tree story, metric tons/ha of dry substance

Tree species	Whortleberry-spruce					Blueberry-pine				
	Needles (leaves)	Bran-ches	Trunk	Roots	Total	Needles (leaves)	Bran-ches	Trunk	Roots	Total
Spruce	2,3172	4,0560	20,2155	8,1853	34,7740	0,1992	0,4781	3,0230	1,1905	4,8908
Pine	0,2757	0,6500	2,7400	1,1097	4,7754	2,3461	5,4896	27,7646	10,9316	46,5319
Birch	0,2110	0,6145	4,9245	1,9935	7,7435	0,5062	1,3916	12,2925	4,8385	19,0288
Willow	—	—	—	—	—	0,1794	0,2682	2,1196	0,8346	3,4018
Total	2,8039	5,3205	27,8800	11,2885	47,2929	3,2309	7,6275	45,1997	17,7952	73,8533

Note: Comma represents decimal point.

Table 4

Nitrogen content and ash composition of the trees, % of pure ash

Part of tree	Nitro. content % of dry substance	Pure ash, % of dry substance	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	CaO	MgO	MnO	K_2O	Na_2O	SO_3
	Whortleberry-spruce											
Spruce, needles	0,84	2,72	24,39	8,67	0,30	5,36	26,61	4,20	3,43	16,70	1,51	3,28
Same, branches	0,74	1,44	9,42	4,09	1,24	8,46	28,96	7,36	2,51	20,40	1,85	5,21
Same, trunk	0,09	0,37	8,79	5,18	1,14	10,21	35,87	7,74	3,71	14,20	1,89	8,21
Pine, needles	0,62	1,53	4,92	7,14	1,28	7,12	34,19	8,49	7,67	20,78	2,69	3,57
Same, branches	0,56	0,83	3,06	5,19	1,31	6,19	43,11	9,16	4,91	17,19	1,83	4,13
Same, trunk	0,09	0,24	2,41	4,15	0,62	3,50	40,17	10,31	4,49	12,26	1,13	12,87
Birch, leaves	2,20	3,03	3,38	12,19	0,60	5,27	20,98	11,86	3,73	28,17	1,88	6,19
Same, branches	0,22	1,14	8,07	13,13	0,61	7,21	34,57	5,72	3,48	10,45	1,08	8,63
Same, trunk	0,10	0,22	11,09	6,50	0,91	5,17	40,66	7,43	2,65	9,54	1,33	10,99
Roots in A_0	0,41	1,10	6,13	5,00	1,30	9,44	26,26	7,44	4,57	21,26	1,38	7,78
Same, A_2	0,32	1,25	6,76	13,20	2,61	7,91	21,14	8,20	4,92	20,81	1,40	4,31
Same, B	0,39	1,67	6,53	29,18	5,16	8,46	18,17	8,01	2,17	13,13	1,25	3,16
	Blueberry-pine											
Pine, needles	0,80	1,46	5,13	6,06	1,16	7,16	32,81	8,01	7,32	22,18	1,99	4,58
Same, branches	0,49	0,98	2,91	6,19	0,76	4,88	41,16	7,96	5,16	16,38	1,06	5,47
Same, trunk	0,13	0,47	1,98	3,71	0,99	5,26	43,23	10,19	4,13	16,81	1,18	8,49
Spruce, needles	0,88	2,94	22,91	7,19	0,29	6,03	26,19	5,83	5,96	16,58	0,66	3,17
Same, branches	0,63	1,29	7,16	6,38	1,16	10,18	27,58	7,19	3,16	17,61	1,12	8,19
Same, trunk	0,11	0,32	6,13	6,19	1,31	11,38	38,16	7,58	4,10	14,19	1,85	8,83
Birch, leaves	2,09	3,86	2,96	9,67	0,61	6,13	21,31	13,16	4,07	29,16	1,56	6,06
Same, branches	0,31	0,92	5,62	6,01	0,44	8,88	35,26	6,49	3,37	11,99	2,63	9,36
Same, trunk	0,12	0,27	13,37	6,38	0,75	5,69	43,06	7,45	2,61	10,86	1,60	10,90
Willow, leaves	2,07	5,83	2,05	1,38	0,34	5,66	47,85	3,29	0,14	26,00	0,39	3,17
Same, branches	0,83	1,56	3,92	1,83	0,83	4,92	56,31	3,38	0,32	14,07	1,03	4,58
Same, trunk	0,31	1,08	3,33	4,50	0,51	5,07	56,09	3,76	0,59	8,85	1,72	8,02
Roots in A_0	0,43	1,03	5,58	6,18	2,41	9,18	27,91	8,28	4,81	20,75	0,91	8,29
Same, A_2	0,34	1,46	7,19	15,91	3,15	12,06	18,15	7,91	1,76	21,17	0,56	7,19
Same, B	0,37	2,13	7,31	32,16	4,82	5,97	11,78	8,56	2,02	12,96	1,03	6,18

Note: Potassium and sodium in all the plants were determined at our request in the Spectral Laboratory of the Dokuchayev Soil Institute, Academy of Sciences of the USSR.

Note: Comma represents decimal point.

Table 5

Accumulation of nitrogen and ash elements in green-moss forests, kg/ha of dry substance

Plant	Nitrogen	Pure ash	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	CaO	MgO	MnO	K_2O	Na_2O	SO_3
						Whortleberry-spruce						
Tree story	125,755	370,192	38,250	28,258	4,819	30,219	107,241	26,548	13,897	66,065	5,898	23,060
Shrub story	33,586	69,186	4.882	1,646	0,756	6,497	19,935	7,032	4,220	13,200	1,979	6,049
Moss cover	10,347	31,722	10,813	1,092	0,921	2 888	5,219	2,581	1,001	4,241	0,682	1,353
Grass cover	0,905	3,589	0,776	0,061	0,015	0,161	0,566	0,158	0,074	1,417	0,067	0,288
Total	170,593	474,689	54,721	31,060	6,511	39,765	132,961	36,319	19,192	84,923	8,626	30,750
					Blueberry-pine							
Tree story	207,441	482,708	24,870	32,333	7,120	34,051	163,599	38,768	19,702	85,657	5,552	35,546
Shrub story	63,350	106,070	6,938	3,053	1,752	10,729	38,373	11,444	5,919	18,881	1,563	10,384
Moss cover	26,288	76,510	20,697	2,923	2,433	7,926	14,164	6,827	0,922	14,439	1,118	3,904
Grass cover	4,554	20,957	4,241	0,566	0,049	0,867	3,644	1,297	0,462	8,455	0,227	0,891
Total	301,633	686,245	56,746	38,875	11,354	53,573	219,780	58,336	27,005	127,432	8,460	50,725

Note: Comma represents decimal point.

Table 6

Average composition of vegetative ash by stories and the total composition of soil horizons, % of pure ash and ignited soil

Forest type	Subject investigated	Pure ash % of dry substn.	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	CaO	MgO	MnO	K_2O	Na_2O	SO_3
Whortle-berry-spruce	Tree story	0,78	10,38	7,69	1,28	8,20	29,10	7,18	3,72	17,95	1,54	6,28
	Shrub story	1,71	7,08	2,40	1,11	9,42	28,89	10,18	6,14	19,12	2,87	8,77
	Moss cover	2,79	34,08	3,44	2,89	9,09	16,44	8,13	3,14	13,38	2,14	6,28
	Grass cover	4,48	21,63	1,69	0,43	4,48	15,75	4,40	2,05	39,49	1,88	8,02
	Forest litter, A_0	3,05	30,75	16,62	6,69	2,75	19,18	5,18	3,38	5,54	1,28	1,97
	Soil, A_2 horizon	—	77,98	12,03	1,82	0,11	2,05	0,93	0,05	2,11	1,03	0,04
	Same, B_1 horizon	—	71,17	16,46	3,47	0,29	4,06	1,18	0,09	2,87	1,23	0,10
Blueberry-pine	Tree story	0,65	5,23	6,77	1,54	7,08	34,15	8,00	4,15	17,85	1,23	7,38
	Shrub story	1,59	6,54	2,89	1,64	10,13	36,16	10,75	5,60	17,80	1,45	9,81
	Moss cover	3,90	27,05	3,81	3,17	10,36	18,50	8,91	1,21	18,88	1,47	5,10
	Grass cover	7,81	18,47	2,78	0,22	4,30	17,60	6,46	2,30	41,70	1,04	4,24
	Soil, A_T horizon	7,65	24,69	20,39	12,43	1,52	20,29	3,39	1,48	4,29	0,81	1,78
	Soil, A_2 horizon	—	70,55	14,54	4,41	0,27	3,81	1,54	0,08	2,67	1,16	0,06
	Same, B_1 horizon	—	69,88	15,54	5,47	0,37	4,02	1,83	0,12	2,84	1,01	0,07

Note: The average ash composition of vegetation was calculated in the following manner: data on dry mass, pure ash, and mineral elements contained in each plant species per hectare, were correspondingly summed by stories. The average content of ash elements and pure ash were calculated in grams per 100 g of dry substance. The obtained data were reduced to percentages of pure ash.

Note: Comma represents decimal point.

spruce and pine forests of more southern regions (11), we will find that it is considerably lower under the conditions of the Kola Peninsula. The blueberry-pine forest is characterized by a considerable accumulation of silica, the content of which is almost the same in both forest types in spite of the great difference in their vegetative mass. Moreover, this can also be explained by the high content of silicic acid in spruce needles. The intense removal of silicic acid from the soil by the vegetation of the whortleberry-spruce forest has a noticeable effect on the intensity of ash formation, which is considerably higher in the iron-humic podzol in the whortleberry-spruce forest than in the peaty-humic podzol of the blueberry-pine forest. The influence of spruce on podzol formation has been repeatedly stressed in the literature (8, 11, etc.), and therefore there is no need to discuss this problem in detail.

The relatively high content of manganese in the vegetation of the spruce and pine forest is noteworthy. According to the data available for central taiga conditions (11), the accumulation of manganese in the vegetative mass of spruce and pine forests is several times lower than their alumina content. In the forests studied by us the alumina content accumulates in amounts only slightly exceeding manganese. Under these conditions manganese apparently possesses a high migration capacity, since there is always a deficiency in calcium in coarsely-textured podzolic soils. Whether this is generally characteristic of northern taiga conditions is difficult to say, since the accumulation of manganese by plants can be associated with its high content in the underlying materials. The accumulation of manganese by cultivated plants under conditions of calcium deficiency has been noted by Pryanishnikov (10) and that by shrubs, has been reported by Levina (7), who made her investigations in a green-moss pine, located 30 km from the forests studied by us.

A great role is played by shrubs and moss in the accumulation of individual elements. Thus, the moss in both types of forests contains a considerable amount of silica and iron. Shrubs accumulate in their mass a large amount of phosphorus, magnesium, and manganese, as well as sulfur and nitrogen (up to 15%-20% of the total content in the entire vegetative mass).

The absolute amounts of individual elements accumulated per unit area, examined by us, permit us to judge the role of vegetation in the redistribution of mineral elements along the soil profile. However, the intensity of the migration of elements under the influence of vegetation is even more pronounced when we compare the ash composition of the plants with the content of chemical elements in the soil. In order to do this biological absorption series have been constructed (9). First the average ash composition of the vegetation was calculated by stories (Table 6) on the basis of the foregoing data (Tables 3 and 4). Under the conditions prevailing in the Kola Peninsula, podzolic soils are sharply divided into genetic horizons, and therefore the biological absorption series were constructed relative to the main soil horizons.

Biological absorption series for the vegetation of the whortleberry-spruce forest, constructed relative to the A_1 and B_2 horizons, are very similar, in spite of the difference in the chemical composition of these horizons. There was also a great similarity between the absorption series for trees and shrubs; the only difference being that the absorption coefficients in the series for shrubs are somewhat higher than the coefficients in the series for trees.

Sulfur, phosphorus, and manganese are characterized by the highest absorption intensity. Iron, aluminum, and silica are absorbed with the least intensity, whereby silica generally occupies the last place in the series according to absorption intensity.

The ash composition of the forest litter differs sharply from the total chemical composition of the mineral soil horizons and therefore the nature of the distribution of elements in absorption series constructed relative to the A_0 horizon is somewhat different. The absorption coefficients in these series are small and close to each other.

The biological absorption series in the blueberry-pine forest are of a similar nature. Both types of forest are characterized by the relatively high absorption of silica by moss. Grass cover is characterized by weak calcium absorption as compared to the forest litter horizon.

Conclusions

1. Vegetation in the northern taiga accumulates considerably less nitrogen and ash elements than that in more southern regions because of the small ash content and insignificant annual growth.

2. The accumulation of mineral elements and nitrogen by the total vegetative mass is much more intense under conditions of an elementary supra-aqueous landscape (blueberry-pine forest) than under conditions of an eluvial landscape (whortleberry-spruce).

3. There is a high accumulation of manganese by the vegetation.

4. Biological absorption series for individual stories, constructed relative to the mineral A_2 and B horizons, have a similar nature in both types of forests: sulfur, manganese, and phosphorus are most intensely absorbed by trees and shrubs. Iron, aluminum, and silica are absorbed the least. Moss cover plays an important role in the accumulation of silica and iron.

5. Shrubs play an important role in the accumulation of mineral elements and nitrogen in the Kola Peninsula as compared with

Table 7

Biological absorption series

Whortleberry-spruce

Compared with A_0 horizons

Tree story	K 3,2	S 3,2	P 3,0	Ca 1,5	Mg 1,4	Na 1,2	Mn 1,1	‖ Al ‖ 0,5	Si 0,3	Fe 0,2
Shrub story	S 4,5	K 3,5	P 3,4	Na 2,2	Mg 2,0	Mn 1,8	Ca 1,5	‖ Si ‖ 0,2	Fe 0,2	Al 0,1
Moss cover	P 3,3	S 3,2	K 2,4	Na 1,7	Mg 1,6	Si 1,1	‖ Mn ‖ 0,9	Ca 0,9	Fe 0,4	Al 0,2
Grass cover	K 7,1	S 4,1	P 1,6	Na 1,5	‖ Mg ‖ 0,9	Ca 0,8	Si 0,7	Mn 0,6	Al 0,1	Fe 0,1

Compared with A_2 horizons

Tree story	S 157,0	P 74,5	Mn 74,4	│ Ca │ 14,2	K 8,5	Mg 7,7	Na 1,5	‖ Fe ‖ 0,7	Al 0,6	Si 0,1
Shrub story	S 219,3	Mn 122,8	P 85,6	│ Ca │ 14,1	Mg 10,1	K 9,1	Na 2,8	‖ Fe ‖ 0,6	Al 0,2	Si 0,1
Grass cover	S 200,1	Mn 41,0	P 41,0	│ K │ 18,7	Ca 18,7	Mg 4,7	Na 1,8	‖ Si ‖ 0,3	Fe 0,2	Al 0,1

Compared with B_1 horizons

Tree story	S 62,8	Mn 41,0	P 28,3	│ Ca │ 7,2	K 6,3	Mg 6,1	Na 1,3	‖ Al ‖ 0,5	Fe 0,4	Si 0,2
Shrub story	S 87,7	Mn 68,2	P 32,5	│ Mg │ 8,6	Ca 7,1	K 6,3	Na 2,3	‖ Fe ‖ 0,3	Al 0,2	Si 0,1

Blueberry-pine

Compared with A_T horizons

Tree story	P 4,6	K 4,2	S 4,1	Mn 2,8	Mg 2,4	Ca 1,7	Na 1,5	‖ Al ‖ 0,3	Si 0,2	Fe 0,1
Shrub story	P 6,6	S 5,5	K 4,1	Mn 3,8	Mg 3,2	Na 1,8	Ca 1,8	‖ Si ‖ 0,3	Fe 0,1	Al 0,1
Moss cover	P 6,8	K 4,4	S 2,9	Mg 2,6	Na 1,8	Si 1,1	‖ Ca ‖ 0,9	Mn 0,8	Fe 0,3	Al 0,2
Grass cover	K 9,7	P 2,8	S 2,4	Mg 1,9	Mn 1,6	Na 1,3	‖ Ca ‖ 0,9	Si 0,8	Al 0,1	Fe 0,02

Compared with A_2 horizons

Tree story	S 123,0	Mn 51,9	P 26,2	│ Ca │ 9,0	K 6,7	Mg 5,2	Na 1,1	‖ Al ‖ 0,5	Fe 0,3	Si 0,1
Shrub story	S 163,5	Mn 70,0	P 37,5	│ Ca │ 9,5	Mg 7,0	K 6,7	Na 1,2	‖ Fe ‖ 0,4	Al 0,2	Si 0,1

Compared with B horizons

Tree story	S 105,4	Mn 34,6	P 19,1	│ Ca │ 8,5	K 6,3	Mg 4,4	Na 1,2	‖ Al ‖ 0,4	Fe 0,3	Si 0,1
Shrub story	S 129,7	Mn 42,4	P 25,0	│ Ca │ 9,0	K 6,3	Mg 5,9	Na 1,4	‖ Fe ‖ 0,3	Al 0,2	Si 0,1

Note: Comma represents decimal point.

conditions in the central taiga.

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EXPERIMENTAL USE OF HUMIC AND POLYMER PREPARATIONS FOR THE IMPROVEMENT OF SIEROZEM STRUCTURE AND EROSION CONTROL

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"If we could find an economical method of artificial aggregation ... our agricultural practices would experience a great revolution ... a revolution similar to that experienced in Western Europe when mineral fertilizers were introduced on a large scale", which lead to the doubling of former yields. This opinion of Academician Tyurin (21) expresses best the importance of the subject discussed in the present paper.

The generalization of soil structure studies conducted in the Soviet Union and abroad (1, 3, 11, 12, 19, 26, 15, 25, 34) leads to the conclusion that the agriculturally important role of soil structure is recognized by the majority of scientists and practical men. Individual statements and observations deny the role of structure (9, 26, 33), or consider it not "absolutely necessary" (18), but they are rare. A decisive role in the formation of the opinion of foreign investigators on soil structure was played by the Soviet school of "structure proponents," a fact which has been repeatedly mentioned in the foreign literature (28, 15, 25).

However, there is still no single point of view among soil scientists and agronomists on the role of structure in the irrigated soils of the sierozem belt of Central Asia, where such an important crop as cotton is grown. Part of the soil scientists and agronomists, and many practical workers, in particular, deny the importance of soil structure, while others believe it to be indispensible (19, 20). The available data on this problem are generalized in our paper with Ryzhov (8).

As we know, the content of water-stable aggregates >0.25 mm in diameter rarely exceeds 10%-20%, and is sometimes less than 5% in irrigated old arable soil under cotton. In the opinion of Vil'yams, sustantiated by the experimental investigations of the Agricultural Physics Institute (16), this percentage must be of the order of 70. Until now nobody was able to achieve such structure in sierozems.

For this purpose we used a number of Soviet and foreign artificial soil conditioners, i. e., used the new trend, developed by Vershinin (4) and now being worked out in many countries of the world (29, 30, 32, 34). Investigations on this problem are being conducted under the supervision of the author at the Institute of Soil Science of the Uzbek Academy of Agricultural Sciences since 1958 together with the Chair of Soil Science of the Tashkent Agricultural Institute, the Institute of Chemistry of the Academy of Sciences of the Uzbek SSR, the All-Union Scientific-Research Institute of Cotton Growing, the Institute of Railroad Transportation, and others.

Objectives of Investigation

We used primarily the A_{plowed} layer (0-30 cm) of a typical, irrigated, fine clay loam sierozem on loess clay loam as the object of investigation. The sierozem is of the Golodnaya steppe age (third terrace), old arable, under cotton. The samples were taken in the territory of the Uzbek Institute of Mechanization (Tashkent Oblast', Oktyabr'skiy rayon). The content in physical clay is 47.7% according to Bratchev's definition, and 56.6% according to Kachinskiy's definition; the fine clay content is 17.7% and 22.4%, respectively; the content of coarse silt is 42.1% and 45.5%; that of total silt, about 73%, and that of true microaggregates, 13.6%. Specific gravity is 2.66, bulk density, 1.28 g/cm^3, total porosity, 51.9%, maximum hygroscopicity, 4.77; maximum molecular capacity according to Lebedev is 14.5%, and the plastic number is 13.4. The humus content is 1.38% total nitrogen, 0.088%; total phosphorus, 0.200%, SO_4 gypsum, 1.148%; CO_2 carbonates, 8.18%, and the solid residue is 0.080%.

Method of Investigation

The experiments were made in the laboratory, in greenhouse pots and in microplots in the field. The results of the latter experiments will be published at a later date.

Twenty-gram samples of aggregates 2-3 mm, < 1 mm, and < 0.25 mm in diameter were used in the laboratory experiments. The samples were wetted with 5 cm^3 of water (control) or a solution of the precipitation, i. e., approximately to find moisture capacity. The preparations were added: a) in a dry state and mixed; b) in the form of a solution and mixed; c) in the form of a solution without mixing. The amounts used were 0.05%-1% of soil weight. The structure was analyzed for stability according to the method of Pavlov, as modified by the All-Union Scientific-Research Institute of Cotton Growing; 1) three days after wetting, i. e., at full maturity; 2) after two weeks of drying in the air; and 3) after three months. The experiments were in duplicate.

In addition we studied the influence of the preparations on the internal aggregate porosity (slide method and paraffinization); maximum hygroscopicity, according to Kachinskiy; erodibility according to Gussak (6); resistance to disperision by rain drops, according to Vilenskiy (5); evaporation, and filtration and rate of salt removal (in solonchak samples from the Golodnaya steppe, Profile 7, M. U. Umarov).

Preliminary experiments were started on the mechanisms of the interaction between structural-formers and the soil, in particular, the kinetics of coagulation.

Pot experiments with cotton were made in pots with 30 kg of soil according to the method of the All-Union Scientific-Research Institute of Cotton Growing (14) at 70%, 80%, and 60% of full moisture capacity. All the preparations were tested against a non-fertilized background, while Poni-G was also tested against the background of a full fertilizer. The total number of pots used was 132, the experiment being replicated 4 times. The results were subjected to a statistical analysis. Observations of the "effect" and "residual" (1 year later) on the soil were the same as in the laboratory. Observations of plants were the usual, i. e., growth, development, and yield.

The humic, polymer, and other preparations tested were: 1) humic acid from lignin (HA-L), as prepared by A. T. Tadzhiyeva (Institute of Chemistry, Academy of Sciences Uzbek SSR[1]), 2) humic acid from coal (HA-C) from Kzil-Kiya (Uzbekistan) of the same author;[2] 3) calcium lignosulfonate (AC-1), obtained from the S. I. Vol'fkovick Chair, Moscow State University; 4) AC-7 ammonium sulfonate of the same author; 5) polyacrylonitrile, hydrolyzed by R. M. Fedorovich at the Chair of Chemical Technology, Moscow State University (Poni-G); 6) the same preparation but not hydrolyzed (Poni-2); 7) the same preparation, hydrolyzed at the Chair of Coloidal Chemistry, Central Asiatic State University (Poni-G-2); 8) polyacryloamide (Pomid); 9) a copolymer of methacrylic acid and methacrylamide (Co-8); 10) K-4, a preparation of a polymeric nature, synthesized by K. S. Akhmedov (Institute of Chemistry, Academy of Sciences, the Uzbek SSR); 11) an ion-exchange resin, ionite; 12) an American preparation "krilium" of the firm Montsanto, trade-mark "Marloam," obtained from the All-Union Institute of Fertilizers, Agricultural Engineering, and Agricultural Soil Science. These preparations were selected on the basis of a generalization of Soviet and foreign experience, preliminary experiments, and theoretical considerations.

Review of the Major Results

The results of the laboratory experiment on the increase of the water-stability of structural units 2-3 mm in diameter of typical irrigated sierozem are shown in Figure1. Here the "control" is one of the highest amounts of aggregates >0.25 mm in diameter (during analysis by the Pavlov method), obtained after grasses, namely 35>, while during analysis after three months the control was the actual amount of these aggregates, equal to 5%

The best results in stabilizing the structure were obtained from 3 preparations: the American preparation krilium, when used at a rate of 1% of soil weight; the Soviet Poni-G, when used at the same rate; and the Tashkent preparation K-4, when used at a rate of 0.1%-0.2% of soil weight, i. e., at a rate of 10 times smaller. The corresponding amount of agriculturally-valuable aggregates was 90%, 87%, and 67%.

Thus, we were the first to obtain a sierozem structure similar to that of chernozem (Fig. 2). The structure was best preserved after 2 weeks and 3 months when krilium and K-4 were used, the content of aggregates were not changed, while with Poni-G its content decreased from 87% to 59% and 58% after 2 weeks.

Small amounts of krilium produced a considerably smaller aggregating effect, which was short-lived in addition. At the same rates of 0.10%-0.20%, K-4 gave 67%, krilium, 66%, and Poni-G, 60% of aggregates; but the effect of the two latter preparations decreased by more than half after two weeks, while it remained the same with K-4. The same effect was obtained when the amount of the preparations was reduced to 0.05%-0.08%, whereby the amount of stable aggregates with K-4 became constant at 44%-47%. Pomid, which gave 42%-55% stable aggregates at the two foregoing rates of application and the Copolymer-8 showed promise; both gave aggregates which remained stable for more than 3 months; AC-1 had a weak, quickly-disappearing effect, but when used at a rate of 1% its residual effect increased sharply; the amount of stable aggregates increased from 32% during analysis after 3 days to 70% during analysis after 3 months. If verification confirms this conclusion, the preparation of Academician Vol'fkovich will be very promising. Humic preparations had a weak and temporary effect.

Thus, the new Soviet preparations K-4, Pomid, and Poni-G were more effective when used in small amounts than the American preparations. These preparations achieved not

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[1] The lignin used for hydrolysis had a moisture content of 10.8% and an ash content of 2.3%; the dry, ash-free substance had 61.1% carbon. It was treated with a 9% solution of nitric acid on warming. The precipitate — nitrohumic acid, contained 49.7% carbon, and 2.73% nitrogen.

[2] The crushed coal was treated in a rotating autoclave with 25% nitric acid at a temperature of 140°-145°C and a pressure of 45 atm. The solid residue-nitrohumic acid, contained 61.8% carbon and 2.5% nitrogen; it was fully soluble in alkali.

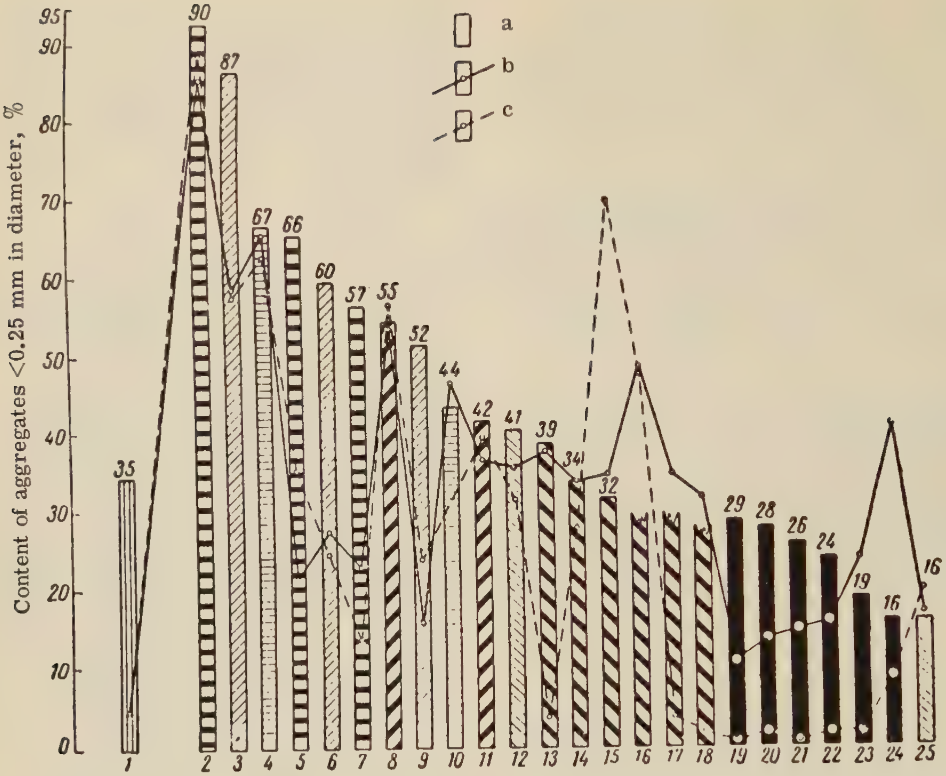

Fig. 1. - Effect of the preparations on the stability of the structure. 1 - 0 - control; 2 - krilium, 1%; 3 - Poni-G, 1%; 4 - 0.10%-0.20%; 5 - krilium, 0.10%-0.20%; 6 - Poni-G, 0.10%-0.20%; 7 - krilium, 0.05%-0.08%; 8 - Pomid, 0.10%-0.20%; 9 - Poni-G, 0.05%-0.08%; 10 - K-4, 0.05%-0.08%; 11 - Pomid, 0.05%-0.08%; 12 - copolymer-8, 0.10%;0.20%; 13 - AC-7,0.10%-0.20%; 14 - AC-7,0.05%-0.08%; 15 - AC-7, 1%; 16 - AC-1, 1%; 17 - AC-1, 0.05%-0.08%; 18 - AC-1, 0.10%-0.20%; 19 - HA-C, 0.05%-0.08%; 20 - HA-L, 0.10%-0.20%; 21 - HA-L, 0.05%-0.08%; 22 - HA-C, 0.10%-0.20%; 23 - HA-C, 1%; 24-HA-L, 1%; 25 - copolymer-8, 0.05%-0.08%; a - after 3 days; b - after 2 weeks; c - after 3 months.

only an increase in the water stability of the already-existing aggregates, but produced the aggregation of small particles into larger ones (Table 1), as noted by Kellogg (28) for krilium.

This is substantiated by the change in the aggregation of sierozems under the influence of polymers, which obey the following patterns: 1) aggregates < 0.01 mm in diameter do not participate in structure formation; their content remains the same under all laboratory treatments and equal to the control, i. e., from 2%-7%; 2) all the changes in aggregate composition caused by the preparations lead to the decrease in the content of aggregates 0.25-0.01 mm in diameter, especially those 0.25-0.05 mm in diameter; and 3) aggregates >1 mm in diameter, i. e., agriculturally the most valuable, increase most sharply among aggregates >0.25 mm in diameter. This has also been noted in the foreign literature.

Consequently, the aggregating effect of polymers consists in the unification of particles 0.28-0.01 mm in diameter into structural units >1 mm in diameter (Table 2).

Dimo (10) obtained another change in the micro-aggregate composition of sod-podzolic soils with the American preparation VAMA and with polyacrylonitril from the German Democratic Republic — the aggregation of sand particles as a result of fine silt and clay. Even though we determined the stability of the structure by another method (Pavlov's) in our experiments, we believe that polymers do not produce such a reconstruction of the microaggregate composition in sierozems. Our laboratory experiments showed that the method of application is of importance with certain preparations (Table 3).

The aggregating effect of Poni-G and krilium changes somewhat more, depending on the method of their application, than K-4.

The aggregating effect of conditioners was considerably lower in the pot experiments than under laboratory conditions (Table 5). Thus,

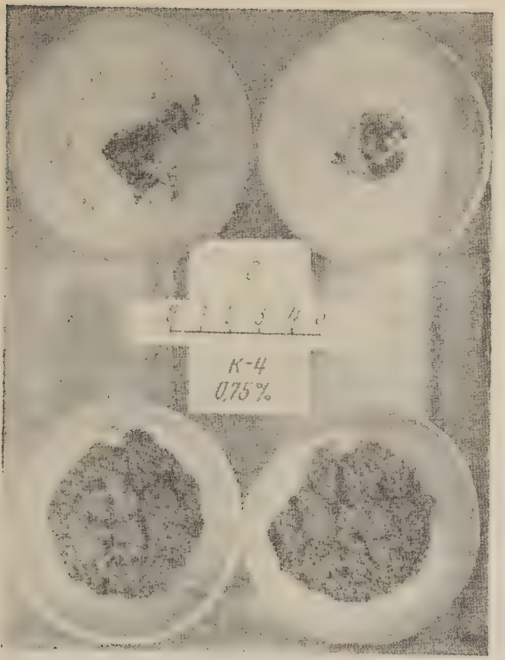

Fig. 2. - Particles larger than 0.25 mm in diameter (according to Pavlov) in the typical irrigated sierozem. The control is on top and the sample treated with K-4 below.

K-4 produced 44%-47% water-stable aggregates >0.25 mm in diameter (which certain rates and methods of application were used), while in pots it produced only 20% of these aggregates at the same rates and methods of application; Poni-G produced 25%-60% and 18%, respectively. Apparently we could not achieve such a complete contact between the soil and the preparation in the pots. This is a very important condition, the role of which will increase in field experiments and under production conditions.

It is also possible that the method of determining the water stability of the structure by Pavlov's method is too "harsh" for detecting fine differences in the structure obtained in the experiment. This was also mentioned at the International Symposium at Gent in 1958 (34).

During the first period of observation (summer) the macrostructure was best preserved in the upper 15 cm of soil in pots treated with 1 metric ton/ha of K-4; it contained 20% water-stable aggregates >0.25 mm in diameter, while the control contained 12%-14%. Then follow Poni-G with 18%, the low amount of K-4 with 17%, Pomid with 14%, and Co-8 with 12%-14%. All the other preparations did not produce an aggregating effect in the pots. At the end of the growing period the content of the agriculturally valuable structure decreased sharply in all the pots, whereby it decreased to 1%-2% in the control. As in the laboratory experiments, the most stable structure was obtained with K-4; its content decreased from 20% to 16%-17% from summer to autumn, i. e., was 8 times greater by autumn than in the control. It decreased from 18% to 10% under treatment with Poni-G, from 14% to 6% with Pomid, and from 12% to 5% with Co-8.

Table 1

Water-stable aggregates >0.25 mm in diameter by Pavlov's method in sierozems with varying initial aggregate sizes

Amount used, % of sample	K-4			Pomid		
	After			After		
	3 days	2 weeks	3 months	3 days	2 weeks	3 months
Diameter of initial aggregates <1 mm						
Control	1—5	1—5	1—5	1—5	1—5	1—5
0,05—0,08	40	43	—	38	41	44
0,10—0,20	58	64	61	42	49	41
Diameter of initial aggregates <0.75 mm						
Control	0	0	0	0	0	0
0,05—0,08	38	40	—	21	22	28
0,10—0,20	53	54	47	26	24	24

Evaporation from pots without plants during the growing period was 33.9 liters/pot in the control, 33.5 liters/pot from the upper 15 cm in the pot treated with 0.01% Pomid, and 27.1 liters/pot from the same layer in the pot treated with 0.05% K-4, i. e., 20% lower than from the control. This decrease is statistically reliable. Shtatnov (All-Union Institute of Fertilizers, Agricultural Engineering, and Agricultural Soil Science) obtained a

Table 2

Influence of polymers on the structure of typical irrigated sierozem

Treatment	% aggregates during analysis by the Pavlov method of diameters				
	>1 мм	1,0–0,25	0,25–0,05	0,05–0,01	<0,01
Control	1	2	72	22	3
Pomid, 0.16%, method of application "b"	53	1	34	10	2
Same, 0.08%	32	5	40	16	7
K-4, 0.75%, method of application "c"	63	2	23	10	2

Table 3

Effectiveness of the preparations depending on the method of application

Amounts, % of sample	% aggregates >0.25 mm in diameter by Pavlov's method								
	Poni-G			Krilium			K-4		
	After			After			After		
	3 days	2 weeks	3 months	3 days	2 weeks	3 months	3 days	2 weeks	3 months
	Method of application "a"								
Control	35	35	5	35	35	5	—	—	—
0,05—0,08	36	10	12	35	12	6	—	—	—
0,10—0,20	42	24	13	39	13	9	—	—	—
1,0	67	71	71	74	35	44	—	—	—
	Method of application "b"								
Control	35	35	5	35	35	5	35	35	35
0,05—0,08	52	16	24	57	23	24	47	47	—
0,10—0,20	60	28	25	66	22	36	67	66	63
1,0	87	59	58	93	86	89	—	—	—
	Method of application "c"								
Control	35	35	5	35	35	5	35	35	5
0,05—0,08	51	11	13	55	50	20	43	49	—
0,10—0,20	66	27	21	84	83	31	65	66	66
1,0	89	29	56	88	84	76	—	—	—

Table 4

Erodibility of sierozem

Treatment	Units of measurement	Replicates	M liters	σ	m	V	P
Initial soil	ml/100 g of soil in the pan	10	3,5	0,5	0,1	13,1	4,1
Same + K-4; 0,005%	Same	10	5,7	0,6	0,2	11,0	3,5
" +K-4; 0,05%	% of soil removed after the passage of 10 liters of water	5	52,9	2,1	1,0	4,0	1,8

Note: M is an average; σ is the average standard deviation; m is the standard error; V is the coefficient of variation; P is experimental accuracy. Data of D. Ismatov.

Note: Comma represents decimal point.

decrease in evaporation of more than 50% when sierozem soil was treated with krilium.

A. N. Ursulov (23) established in a laboratory experiment with thick, coarse clay loam chernozem from the Kurs Oblast' that in the absence of wind, less moisture evaporates from aggregates 2-3 mm in diameter than from finer aggregates or from soil which had not been broken up.

Should our conclusions be confirmed, they will be of great importance since they show that it is possible to economize on irrigation water when polymers are used.

The microscopic examination of polished sections (G. I. Vaylert) did not disclose any sharp differences in the porosity of the aggregate in the control and that treated with a polymer.[3]

The paraffined aggregates revealed an insignificant increase in the porosity of aggregates under the influence of polymers: if porosity was 31.6% in the control, it increased to 32.6% under treatment with 0.01% Pomid; to 37.8% under treatment with 0.01% Co-8; and to 32.3% under treatment with K-4. All the increases are reliable. The Co-8 has the most friable effect; it produced the same aggregate porosity as 3-year old alfalfa, which produced a porosity of 37.6%.

Maximum hygroscopicity remained practically unchanged under treatment with the polymers studied.

Tests on the effect of polymers on the erodibility of sierozem showed that the removal of 100 cm³ of soil from the pan requires the following amounts of water (Table 4):

The control aggregates of 2-3 mm in diameter, subjected to a stream of water (in a special pan) of a standard depth and rate, immediately breaks up into micro-aggregates which are carried away by the stream; aggregates treated with K-4 practically do not break up under such a stream for an indefinite period of time. When immersed into a test tube with water, the former break up immediately, while the latter have been kept by us for more than 1 year without showing noticeable signs of deformation. Finally, the study of the resistance of such aggregates to rain showed that the aggregate in the control broke up after 0.7 ml of rain, while the aggregate treated with K-4 (0.5%) did not wash away even after a rain of 1500 ml.

Thus, polymers of the type of K-4 radically change the relation between soil and water, increase its resistance to soaking, erosion, washing, and to the impact of rain drops. This is evidence of the great soil changes caused by polymers and of the promise polymers show for the control of irrigation erosion.

In the experiment of Shtatnov with our sierozem soil, krilium produced the following changes in the percolation of tubes in two hours: the control percolated 37 ml; with 0.025% krilium percolation was 70 ml; with 0.05% krilium it was 72 ml; with 0.1% krilium it was 250 ml; and with 0.3% krilium it was 878 ml, i. e., 20 times higher than for the control.

In our experiments with funnels on the leaching of solonchak we were able to remove chloride and sulfates from the control after 6 days and 10 hrs, using 7.3 liters of water, while the salts were removed with 10 liters of water after 4 days and 10 hrs from the sample treated with K-4, whereby chloride was removed in 10 hrs from the control and in 4 hrs from the sampling with K-4.

The method of leaching salts with the aid of polymers can be used during the preparation of soils for particle-size analysis by the Kachinskiy method, and, if substantiated under field conditions, it could be used in practice.

As we can see from Table 5, humic and polymer preparations had a many-sided effect on the growth, development, moisture requirement, and yield of cotton. Under their influence the period between sowing and flowering and ripening was shortened both against a background of fertilizers and without them. Such an "increase" in the speed of cotton ripening is of great practical importance, since it would allow us to begin agricultural work earlier in the autumn and increase the quality of the fiber.

In our experiments the coefficient of water consumption, i. e., water used to produce 1 metric ton of raw cotton, was 3200 m³/metric ton against a background without fertilizers, and 1080 m³/metric ton against a fertilized background; in samples treated with polymers this coefficient varied from 1800-2800 m³/metric ton. Its closeness, in certain cases, to the water consumption by the non-fertilized control is a confirmation of the fact that the effect of these preparations is not determined by nutrient elements, but by some other properties.

All the preparations studied under all rates and methods of application produced an increase in raw cotton yield both against a background without and with fertilizers: in the first case the increment varied from 4% to 100% (i. e., in one case the yield doubled), and in the second case it reached a reliable 14%. The highest yield per unit preparation used was obtained from small amounts of Co-8, Pomid, and K-4. All polymers increased the pre-frost harvest, even as compared to the control, while they also increased the weight of the bolls against a background without fertilizers.

Discussion of Results

It remains to decide to what degree these changes correlate with the improvement in

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[3] The method used was that recommended by us of polishing a pair of aggregates, joined on a single glass; the obtained negative was supposed to be evaluated by means of an MF-2 microphotometer, but this work has not been finished yet.

Table 5

Indices of the effectiveness of aggregation in the pot experiment with cotton in 1959 with the A_{plowed} horizon of a typical irrigated sierozem (data of V. B. Gussak and V. M. Mukol'yants)

Treatment	Amount		Yield					Water consumption		Duration of the period since sowing		Aggr.>0.25 mm in diam. (by Pavlov's mh)	
	Metric tons/ha, 15-cm layer	% of wt.	Total, g/pot	Incr., % of control	Pre-frost harvest, %	Wt. of first boll	Yield per unit preparation	Liters/pot	m^3/mt ton of r.cotn.	Prior to flowering	Prior to ripening	Summer, 6-25	Autm. Oct. 25
O	—	—	24,6	100	69,9	4,6	—	77,9	3,200	68	123	7	1,4
O without plants	—	—	—	—	—	—	—	33,9	—	—	—	10	1,2
O + NPK	—	—	113,7	100	79,2	6,5	—	123,2	1,080	62	112	6	1,3
O + NPK without plants	—	—	—	—	—	—	—	33,5	—	—	—	2	1,7
Humic acid from lignin (preparation of A. Tadzhiyev) HA-L	C[a] 1,0	0,05	40,5	65,0	70,6	4,8	5,4	82,9	2,300	63	117	5	1,0
	C[a] 10,0	0,5	49,1	99,5	77,6	4,8	0,7	92,9	1,900	61	115	7	1,5
Same	S[a] 1,0	0,05	31,2	26,8	59,9	4,6	4,2	78,4	2,600	67	123	6	1,2
"	S[a] 2,0	0,1	32,1	30,5	80,0	4,9	2,1	72,1	2,300	63	118	9	1,4
"	S[a] 10,0	0,5	31,0	26,1	54,9	4,4	0,4	71,2	2,300	65	127	7	1,2
Polyacrylonitril-2, Poni-2	D 1,0	0,05	28,9	17,5	66,4	4,4	3,8	71,8	2,500	66	120	6	1,6
"	D 2,0	0,1	34,1	38,6	57,2	4,5	2,3	60,8	1,800	66	125	5	1,6
"	D 10,0	0,5	37,0	50,4	61,1	4,1	0,5	66,3	2,300	63	121	5	1,7
"	S 2,0	0,1	28,8	17,1	91,3	5,0	1,9	71,0	2,500	62	115	7	1,5
"	S 10,0	0,5	28,2	18,0	95,4	4,9	0,4	70,8	2,500	60	113	6	1,6
Polyacrylonitril, hydrolyzed, Poni-G-2	D 1,0	0,05	28,1	14,2	100	5,6	3,7	70,5	2,500	62	113	7	1,3
	D 2,0	0,1	25,5	3,6	86,7	4,8	1,7	68,8	2,500	62	115	7	1,1
Same	S 1,0	0,05	28,3	15,1	80,3	5,7	3,8	71,3	2,800	62	117	7	1,4
"	S 2,0	0,1	26,0	6,0	99,2	5,4	1,7	70,5	2,500	58	113	7	1,6
"	S 10,0	0,5	28,9	17,5	88,6	4,8	0,4	72,0	2,400	62	115	13	2,1
Polyacrylonitril, hydrolyzed in Moscow, Poni-G	1,3[c]	0,2	37,1	50,8	67,4	5,3	3,7	87,9	2,400	54	113	18	10
Same + NPK	1,3[c]	0,2	129,2	13,6[b]	70,6	6,9	12,9	140,7	1,100	55	103	18	10
" + NPK minus 13% N	1,3[c]	0,2	93,7	−17,6[b]	70,5	7,8	9,4	111,4	1,200	58	106	18	11

[a] "D" – in dry form, "S" in solution; in the rest of the cases, except for ionite, – in solution. [b] In % of fertilized control; all the rest in % of non-fertilized control. [c] In a layer 5 cm thick.

Note: Comma represents decimal point.

Table 5 continued

Treatment	Amount		Yield					Water consumption		Duration of the period since sowing		Aggr. >0.25 mm in diam. (by Pavlov's m	
	Metric tons/ha, 15-cm layer	% of wt.	Total, g/pot	Incr., % of control	Pre-frost harvest, %	Wt. of first boll	Yld. per unit preparation	Liters/pot	m³/metric ton of r. cotn.	Prior to flowering	Prior to ripening	Summer, 6-25	Autm. Oct. 25
Polyacryloamide, Pomid	0,1	0,005	35,5	44,3	92,7	5,6	44,4	75,6	2,100	58	109	11	1,7
Same	0,2	0,01	35,2	43,1	91,2	5,9	22,0	81,5	2,300	61	114	14	6
Same without plants	0,2	0,01	—	—	—	—	—	33,6	—	—	—	14	5
Copolymer-8	0,06	0,003	31,5	28,0	100	5,7	63,0	73,2	2,300	61	113	13	1,7
Same	0,2	0,01	38,3	55,7	86,4	5,3	25,5	76,9	2,000	57	114	9	6
"	0,4	0,02	39,2	59,4	66,1	4,5	15,7	81,5	2,000	56	116	12	5
Ionite-PK	0,6	0,03	27,0	9,8	100	6,0	6,8	71,4	2,600	61	117	8	1,2
K-4 (preparation of Akhmedov)	0,2	0,01	36,7	49,2	94,3	5,2	24,5	78,9	2,100	57	107	12	4
Same	1,0	0,05	42,9	74,4	85,0	5,5	5,7	90,6	2,100	58	112	20	17
Same without plants	1,0	0,05	—	—	—	—	—	27,1	—	—	—	17	16

Note: Comma represents decimal point.

structure, even though the latter was not significant, as we have pointed out earlier.

Humic preparations did not give an aggregating effect and produced an increase in yield only because of their nitrogen content and, possibly, their content in microelements (13). If we select samples with a statistically reliable yield increment from the polymers and compare them with the amount of a water-stable aggregates, we will obtain the following series (Table 6).

Incorporating the yields into intervals, we will obtain the following data:

Interval by yield, g/pot	No. of treatments	% aggregates >0.25 mm in diam.	
		Range	Average
Up to 35	2	5–13	9
34–40	7	5–18	12
More than 45	1	—	20

Thus, there is only an insignificant correlation between yield and soil structure, if any. Examples of the insufficient correlation between these values were also mentioned at the fourth session of the International Symposium on Soil Structure in Belgium (34). It was to be expected in our experiments, since there is no reason to believe that yield is an evenly changing function in the whole range of changes in the stability of the structure. It is more probable that the soil suddenly changes from a structureless to a structured state when a certain threshold in the content of water-stable aggregates is reached. Apparently this threshold was not reached in the pot experiments.

Our observations with Smolina (21) showed that a certain role is played by coagulation in the interaction between the soil and polymers, since the degree of soil aggregation correlates well with the kinetics of coagulation: the amounts and preparations which gave the best structure also had a larger sedimentation volume in a soil + polymer suspension and flocculated more rapidly. But the mechanics of this phenomenon remain obscure. As already mentioned, particles 0.25-0.05 mm in diameter enlarge to 1-10 mm in diameter under the effect of polymers; this resembles more the process of cementation than coagulation. But, in the first place this does not agree with the aggregating effect of small amounts of polymer in hundredths or even thousands of a percent, and, secondly, it is contradicted by our observation of the positive effect of polymers in the presence of a large amount of electrolytes. We must confess that the nature of the relations between polymers and soil is more complicated than mere cementation. Further detailed investigations are needed.

Conclusions

1. Irrigated typical sierozem can be aggregated by means of polymer preparations, whereby small amounts of the Soviet Poni-G, K-4,

Table 6

Relationship between the yield of raw cotton and soil structure during pot experiments in 1959 against a non-fertilized background

Treatment	Yield, g/pot	Reliable differences from the control[a]	% aggregates > 0.25 mm in diam. (by Pavlov's mth).	
			Summer	Autumn
Copolymer-8, 0.06 met. t/ha	31,5	3,0	13	1,7
Poni-2 2 "	34,1	3,8	5	1,6
Pomid 0.2 "	35,2	3,0	14	6,0
Same 0.1 "	35,5	3,8	11	1,7
K-4 0.2 "	36,7	5,3	12	4,0
Poni-2 10 "	37,0	5,4	5	1,7
Poni-G 1.3 "	37,1	3,4	18	10
Copolymer-8, 0.2 "	38,3	7,6	9	6
Same 0.4	39,2	5,6	12	5
K-4 1 "	42,9	5,4	20	17

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[a] Calculated by the formula $\frac{M_2 - M_1}{\sqrt{m_2^2 + m_1^2}}$; if this ratio is greater than 3, the difference is significant.

Note: Comma represents decimal point.

and Pomid are more effective than the American krilium, and remain effective longer.

2. Laboratory and pot experiments with cotton showed that under the influence of polymers evaporation of water from the soil decreases, the porosity of aggregates increases in certain cases, the resistance of the soil to erosion increases, and the percolation of sierozem improves.

3. Polymers shorten the period between the phases of cotton development against a background without fertilizers, lower the water requirement per unit of production, increase yield and the portion of the pre-frost harvest, and also increase the weight of bolls. The yield increment from Poni-G against a fertilized background is 14%.

4. No significant correlation was found between yield and the improvement of the soil structure, apparently because the structural level reached in the pots was 3 times lower than the "classical norm."

5. Humic preparations are of interest as a new way of using large amounts of nitrogen and, apparently, as cotton development stimulators.

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ROLE OF GRASS-ARABLE ROTATION CROPS IN THE DYNAMICS OF THE GROUP COMPOSITION OF SOIL AGGREGATES

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Up to the present time soil structure is usually characterized by the amount of water-stable aggregates of various sizes. The quality of the aggregates, i. e., their properties, which determine their role in soil fertility are being studied little. At the same time, Tyullin (7) developed a concept of the qualitative difference between soil aggregates, which arises during their genesis. He showed in his latest works (9, 10, 11) that the majority of humic substances in the soil is bound by adsorption or chemically in the form of organo-mineral films (calcium or iron humates) at the surface of mineral particles not larger than 0.01 mm in diameter, from which water-stable aggregates form primarily. These films-gels contain the major elements of plant nutrition, such as nitrogen, phosphorus, potassium and calcium ions, etc. These are of great importance in the aggregation of clay and fine silt particles in the soil.

The particles which are coated with an iron humate film form micro-aggregates having the capacity to cohere, i. e., enlarge. They are characterized by a high water stability and irreversibility when saturated with sodium cations from a neutral table salt solution (of Gedroyts). Micro-aggregates formed of particles coated with a calcium humate film are also relatively water-stable when fully saturated with calcium and magnesium cations, but peptize easily when bivalent cations are replaced with monovalent cations (including sodium).

Soil aggregates (according to Tyulin) consist of two groups of micro-aggregates: calcium humates (group I) and iron humates (group II), whereby they are the main source of water-stable aggregates in the root zone of the soil. This is confirmed by the latest works of Filippovich (12), Korovkina (5), and Migunova (6).

A. F. Tyulin proposed a method of dividing water-stable aggregates into qualitatively different groups of micro-aggregates, which is called the method of fractional peptization. This method and its simplified modifications (8) were used by us in the study of the aggregating role of plants and the qualitative changes in soil structure in individual phases of grass-arable rotation. The investigations were made in one of the experimental crop rotations at the experimental field of the educational farm of the Ivanov Agricultural Institute. This is a wide seven-field system with the crop sequence: 1) black fallow; 2) winter crops undersown with grasses; 3) and 4) grasses; 5) spring grain; 6) potatoes; and 7) oats.

The soil of the area is a moderately podzolic, silty sandy loam sod soil on fine clay loam, underlain by sand. Its potential ability to aggregate is insignificant, the amount of clay and fine silt not exceeding 13.7%, while the humus content varies around 2%.

We observed the dynamics of the group composition of water-stable aggregates from 1954-1958 in 3 crop rotation fields. In one of them (field II) we found changes in the ratio between 2 groups of aggregates during the period when the sod from perennial grasses was used for annual field crops (1954-1956), in the second field (III) under fallow-winter crops and under grasses in the first year of use, and in the third field (IV) during the two years when grass mixtures were used (1957-1958). Soil samples were taken several times during the growing period: in spring, in summer (including before the harvest), and in autumn. Mixed samples consisting of samples taken from 3 fixed locations in the field were analyzed.

As a result we obtained a considerable amount of data. Figure 1 shows curves characterizing the dynamics of the group composition of aggregates in the plowed layer in the foregoing crop rotation. An analysis of these curves and of the numerical material on the basis of which they were constructed shows a number of patterns which are of interest both from a theoretical and practical point of view.

Seasonal dynamics of two qualitatively different groups of aggregates. Until 1954 there were no data in the literature characterizing the seasonal dynamics of the group composition of water-stable aggregates in field soils. The first results of investigations, begun as early as 1948 by S. M. Kozlova, were published by Tyulin (8). These and the following works of Tyulin and his collaborators showed that during the growing period the water-stable aggregates in the soil are subject to qualitative changes which are easily detected by the method of fractional peptization. These changes are caused by the growth and dying-off of plant

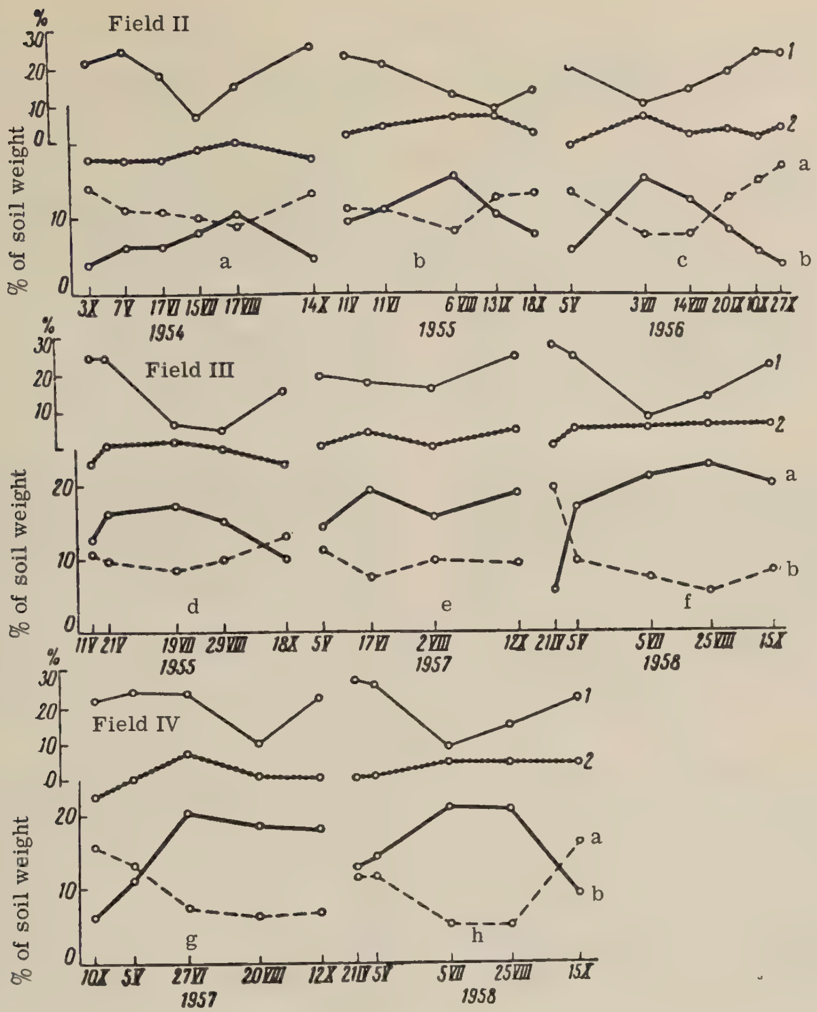

Fig. 1. - Dynamics of the group composition of water-stable aggregates in certain crops under rotation.
a - oats; b - potatoes; c and d - oats; e - winter wheat + grasses; f - g - 1-year old grass; h - 2-year old grass. 1 - soil moisture; 2 - sum of particles <0.01 mm in diameter of group I and II; a - aggregates of group I (calcium humates); b - aggregates of group II (iron humates).

roots and micro-organisms, and by fluctuations of the oxidation-reduction potential of the soil, associated with the rhythmic development of living matter and hydrothermal conditions in the soil.

We can see from the curves presented in Figure 1 that the sum of clay and fine silt particles (<0.01 mm in diameter), removed from water-stable aggregates, changes relatively little from one period of observation to another. On the contrary, the ratio between the particles forming the qualitatively different groups of micro-aggregates fluctuates rather sharply. The curve for the calcium humate aggregates (group I) is like a mirror reflection of the curve for iron humate aggregates (group II), which indicates that one group of micro-aggregates changes into another. The least amount of iron humate aggregates and, correspondingly, the highest number of calcium humate aggregates is found in spring (in early May) and autumn (October). In summer (up to July-August) the proportion of the iron humate fraction in the entire mass of aggregates increases more or less noticeably.

The effect of individual annual crops under rotation and of perennial grasses on soil structure is not the same. We can see it clearly from Table 1, which shows average data of observations made during a number of years.

It follows from these data that both the total amount of water-stable aggregates and the amount of iron humate aggregates (group II) in them increase under perennial grasses. The greatest change in the structure of the soil during the growing period occurs under annual

Table 1

Seasonal change in the group composition of water-stable aggregates in the plowed layer under crops of grass-arable rotation

Sampling time	Under annual crops		Under perennial grasses	
	Sum of aggr. of grps. I and II, %	Group II, % of total	Sum of aggr. of grps. I and II, %	GroupII, % of total
May	20,1	41,2	26,1	59,2
July-August	22,4	60,0	26,9	77,9
October	20,5	33,7	26,9	63,7

Note: Comma represents decimal point.

crops. These differences are associated with the biological peculiarities of the root system of annual and perennial plants, their chemistry, duration of interaction with the soil, and the agricultural practices used (first of all, soil tillage).

Figure 1 also shows the dynamics of soil moisture. By comparing these curves with those of the group composition of aggregates we can easily establish a regular relationship between them. This relationship with respect to group II microaggregates is primarily of

Table 2

Change in the group composition of aggregates during the late autumn-winter-early spring period

Field No.	Year of observation and crop	Sum of aggregates of the I and II groups, % of dry soil			Group II, % of total		
		Autumn	Winter	Spring	Autumn	Winter	Spring
	In 0-10 cm layer						
III	1956-1957. Fallow and winter wheat	21,6	23,8	24,2	17,1	39,4	56,2
	1957-1958. Winter wheat undersown with grasses	26,6	22,6	26,0	65,8	48,7	62,7
IV	1956-1957. Winter wheat undersown with grasses	22,9	24,1	24,3	29,7	21,9	49,4
	1957-1958. Grasses during the 1st year of use	24,9	24,1	26,2	70,7	61,8	64,6
III	1956-1957. Fallow and winter wheat	21,9	24,1	24,9	20,5	39,0	53,4
	1957-1958. Winter wheat undersown with grasses	27,3	22,6	27,5	68,9	47,3	63,3
IV	1956-1957. Winter wheat undersown with grasses	22,6	24,1	24,8	29,6	29,9	49,6
	1957-1958. Grasses during the 1st year of use	25,8	25,3	27,9	73,6	67,6	67,4
	In the plowed layer 0-20 cm						
II	1956-1957. Fallow and winter wheat	21,8	23,9	24,6	18,8	39,2	54,8
	1957-1958. Winter wheat undersown with grasses	27,0	22,6	26,7	67,4	48,0	62,0
IV	1956-1957. Winter wheat undersown with grasses	22,8	24,1	24,6	29,7	25,8	49,5
	1947-1958. Grasses during the 1st year of use	25,4	24,7	27,1	72,2	64,7	66,0

Note: Comma represents decimal point.

the nature of a reverse relationship.

Permanent investigations for a number of years and sampling periods in spring (prior to soil ripening) and autumn (shortly before the onset of persistent frost) make it possible to detect changes in soil structure during the late autumn-winter-early spring period (Fig. 1). In order to determine exactly when (in late autumn or early spring) the changes in the group composition of aggregates take place, we also took soil samples in winter in 1957-1958. The results are summarized in Table 2.

As we can see, iron humate aggregates are decomposed most often in late autumn after the harvest or even prior to it. In early spring, when the soil dries out after having been saturated with water, the amount of aggregates, cemented with iron humates, increases considerably. However, at the beginning, when the soil has thawed and anaerobic conditions prevail in it, iron humate aggregates continue to disintegrate. Thus, for instance, group II aggregates comprised 48% of the sum of particles forming aggregates of the I and II groups in field III (winter wheat undersown with grasses) on January 28, 1958. By April 21 they comprised 30.7%, while by May 5, their amount increased to 62%. It must be noted that the decay and formation of iron humate aggregates during periods when the soil is excessively wet and when it dries out is most intense in the upper half of the plowed layer.

The annual dynamics of the group composition of soil aggregates, as its seasonal dynamics, is associated with soil moisture and to a large degree is determined by it. Thus, the small proportion of group II in the composition of aggregates, found in the autumn of 1953 and 1956 (Fig. 1,), corresponds to the heavy precipitation during the summer-autumn period, which caused the periodic excessive wetting of the plowed layer. There was 440 mm of precipitation in July-September 1953, and 249 mm during the same period in 1956. This considerably exceeded precipitation during the other years of observation.

Role of the root system of plants in the genesis of water-stable aggregates. In order to study the role of the root system of plants in the formation of the structure of sod-podzolic sandy loam soil under grass-arable rotation, areas 4 m² were left unsown in the experimental fields and weeded constantly. The results of the analysis of soil samples taken at various moments during the growing period from under plants and the vegetation-free areas

Table 3

Influence of vegetation on the formation of iron humate aggregates in the soil

Year of observation	Crop	Iron humate aggregates, % of sum of Groups I and II					
		Under plants			In vegetation-free area		
		Spring	Summer (before the harvest)	Autumn	Spring	Summer (before the harvest)	Autumn
		In 0-10 cm layer					
1955	Potatoes	—	52,7	—	—	50,1	—
1956	Oats	—	62,9	—	—	58,1	—
1957	Winter wheat + grasses	56,2	59,8	65,8	59,3	60,0	58,1
	1-year old grass	49,4	75,3	70,7	59,1	68,0	64,4
1958	2-year old grass	64,6	80,4	34,4	66,9	81,6	27,0
		In 10-20 cm layer					
1955	Potatoes	—	42,6	—	—	44,3	—
1956	Oats	—	62,3	—	—	59,3	—
1957	Winter wheat + grasses	53,4	63,0	68,9	55,3	63,7	62,9
	1-year old grass	49,6	72,5	73,6	56,8	71,8	68,2
1958	2-year old grass	67,4	77,8	52,4	62,6	85,3	32,1
		In 0-20 cm plowed layer					
1955	Potatoes	—	45,7	—	—	46,8	—
1956	Oats	—	62,5	—	—	58,7	—
1957	Winter wheat + grasses	54,8	61,4	67,4	57,3	61,8	60,5
	1-year old grass	49,5	73,9	72,2	58,0	69,9	66,3
1958	2-year old grass	66,0	79,1	43,4	64,8	83,5	29,0

Note: Comma represents decimal point.

showed that the sum of particles <0.01 mm in diameter, separated from water-stable aggregates by fractional peptization, depends little on the short-term (1-2 years) influence of the root system; it only shows a certain tendency to increase in the soil under the influence of plants. The group composition of soil aggregates changes considerably in a number of cases under the influence of roots and associated micro-organisms. We can see from Table 3 that during the growing period the group composition of aggregates changes both under plants and in soil not subject to their action. The direction of these changes is the same in principle: iron humate aggregates form in summer, partly disintegrate by autumn, and form calcium humates.

In summer, when the root system grows, the soil gradually dries out, as a rule, and plants have little effect on the change in the group composition of aggregates. In two cases out of five (Table 3, 1956 and 1957) there was somewhat more iron humate aggregates under the plants before the harvest than in root-free soil. In 1958, on the contrary, there was less of these aggregates under grasses than in vegetation-free soil. It is characteristic that in this case there is a definite relation with soil moisture. There was 107 mm of precipitation from June 30-August 20, 1958 and only 66 mm during the same period in 1957. The moisture content of soil samples taken in August 1958 was 13.5% as against 8.5% in August 1957.

In early spring, when the soil dries out after having been excessively wet, iron humate aggregates form more slowly under plants (especially in the upper half of the plowed layer). Actually we found less iron humate aggregates under all experimental crops in spring than in areas bare of vegetation. In autumn, on the contrary, plants had a distinctly favorable effect on the formation of group II aggregates.

Thus, a continuous change in the group composition of water-stable aggregates takes place under grass-arable rotation conditions, which necessarily reflects on the quality of the structure and its role in soil fertility (11, p. 37-46).

The main cementing aggregates in soils poor in calcium, such as sod-podzolic soils, are iron humates.

Biological processes, which take place in the soil and result in the renewed formation of humic substances and iron and aluminum hydroxides, have a decisive effect on the formation of iron humates. Experimental data, discussed in this paper, show that the renewal of iron humate aggregates in the soil under field crops occurs not only under the influence of living roots, but also as a result of the decomposition of dead organic residues. At the same time the decomposition products of organic matter and the life activity of micro-organisms also affect soil minerals, releasing various elements from them, including iron.

A. F. Tyulin associates the decomposition of iron humate aggregates with the change in the oxidation-reduction potential of the soil toward predominantly anaerobic conditions. As we know, iron oxide is reduced under these conditions to ferrous oxide, the iron humate films loose their cementing power, and part of the group II aggregates is decomposed. We can mention papers which show that when sod-podzolic soil is excessively wet, reduction processes arise in it and ferrous oxide accumulates (3, 13, 14 and others).

In order to study the influence of reduction processes on the group composition of water-stable aggregates, the author conducted combined investigations on the dynamics of ferrous oxide in the soil and the seasonal fluctuations of two groups of micro-aggregates from 1957-1958. Iron oxide and ferrous oxide were extracted with a 0.1 N solution of H_2SO_4 and determined colorimetrically with α-α^1 dipyridyl. The most characteristic data are presented in Table 4. The amount of iron humate aggregates is expressed in this case in percentages of dry soil.

If we compare the data obtained for the soil under plants and the soil in the vegetation-free areas, we can see a certain relationship between the content of ferrous oxide and the amount of iron humate aggregates in individual parts of the plowed layer. The amount of aggregates cemented with iron humates decreases in the majority of cases as the content of ferrous oxide in the soil increases, especially when the differences are great. There is no reason to expect a full correlation in this case. Actually, reducible iron compounds are contained in the soil not in the form of films-gels at the surface of particles and aggregates. Iron salts and then its hydrates form constantly as dead plant residues decompose. The iron is most mobile and is reduced first when the oxidation-reduction potential of the soil decreases. Iron humate aggregates do not decompose thereby. Decomposition begins only when iron in the films-gels is reduced under conditions of deep and prolonged anaerobiosis. When evaluating the results we must keep it in mind that ferrous oxide is very mobile in the soil and its presence there may be ephemeral.

Differences between the content of ferrous oxide and group II aggregates in the individual horizons of the plowed layer of soil not subject to the action of living plant roots (vegetation-free areas) are insignificant and often nonexistent.

An interesting picture is observed under plants. As a rule, there was more ferrous oxide here during the same observation periods than in the soil free of vegetation. However, this does not lead to a decrease in the content of iron humate aggregates in the soil. On the contrary, in a number of cases there was more iron humate aggregates under plants than in areas of vegetation. The averages of all the determinations presented in Table 4 clearly show this pattern (Table 5).

The larger amount of ferrous oxide in the upper half of the plowed layer of sod-podzolic soils under plants, where the main root mass is concentrated, is apparently associated with the higher biological activity of the soil in this zone. Actually the main factor in the development of anaerobiosis, as shown

Table 4

Seasonal dynamics of ferrous oxide and iron humate aggregates in crop rotation fields

Field No.	Sampling date	Under plants in the layer				In vegetation-free area in the layer			
		0—10 cm		10—20 cm		0—10 cm		10—20 cm	
		mg/100 g of soil	Iron humate aggregates, %	mg/100 g of soil	Iron humate aggregates, %	mg/100 g of soil	Iron humate aggregates, %	mg/100 g of soil	Iron humate aggregates %
		1957. Winter wheat + grass							
III	May 5	1,8	13,6	1,2	13,3	0,8	14,7	0,8	13,1
	August 2	0,5	15,0	Trace	15,3	Trace	13,8	Trace	15,1
	October 12	11,0	17,5	5,0	18,8	1,5	15,1	0,5	16,6
		1958. Grasses in 1st year of use							
	April 21	2,5	5,0	1,5	6,8	1,0	11,4	1,0	11,4
	May 5	0,5	16,3	0,5	17,4	Trace	16,5	Trace	16,5
	August 25	3,0	21,8	1,5	22,3	0,8	21,8	0,8	22,1
	October 15	0,8	17,7	1,0	21,8	1,5	10,3	3,0	11,4
		1957. Grasses in 1st year of use							
IV	May 5	1,5	10,3	1,1	12,3	0,8	13,3	0,8	12,9
	August 27	2,5	19,8	1,8	20,9	1,0	18,4	Trace	17,8
	October 12		17.6	Trace	19,0	Trace	16,8	"	17,4
		1958. Grasses in 2d year of use							
	April 21	1,5	11,6	1,0	13,9	0,5	6,2	0,5	5,6
	May 5	Trace	14,3	Trace	16,0	None	15,2	None	14,1
	August 25	1,8	21,8	1,8	21,4	4,5	19,8	3,5	20,7
	October 15	5,0	8,9	2,0	11,8	1,8	7,0	1,3	8,8

Note: Comma represents decimal point.

Table 5

Influence of plants on the contents of ferrous oxide and iron humate aggregates at various depths in the soil

Measurement	Under plants		In vegetation-free area	
	0—10	10—20	0—10	10—20
Ferrous oxide, mg/100 g of soil	2,3	1,3	1,1	0,9
Iron humate aggregates, % of dry soil	15,1	16,5	14,2	14,5

Note: Comma represents decimal point.

by Kozlovskiy (4), is the activity of biological processes in the excessively wet horizon. As we well know from studies on gley formation (1), the reduction of iron in the soil is closely related to the biological decomposition of organic matter under anaerobic conditions. Such conditions, however, may also arise when the soil is not excessively wet (excessively wet soil inhibits gas exchange), for instance, in the presence of fresh plant residues in the soil and at its surface, which are subject to intense decomposition. Therefore, bivalent iron is found in the plowed soil layer not only in spring and autumn, but also in summer when the soil is not subject to excess wetting. During the interaction of plants with the soil, such products apparently appear and accumulate in the latter which activate reduction processes.

One or the other amount of iron humate aggregates, present at any moment in the soil, is the result of simultaneous, but opposing processes – their formation and decomposition. On the one hand, biological processes take place in the soil during the decomposition of organic residues and under the influence of living plant roots and rhizosphere microorganisms, which result in the formation of new amounts of humic substances and iron and aluminum hydroxides and create conditions for the constant development of iron humate aggregates. On the other hand, these same processes cause a decrease in the oxidation-reduction potential of the soil, the development of reduction processes, the change in iron oxide compounds to ferrous oxide, and as a result the disintegration of part of the aggregates cemented with iron humates. Data in Table 4 indicate that processes of the renewal of iron humate aggregates predominate under the effect of plants on the soil.

Conclusions

1. The seasonal and annual changes in the group composition of aggregates, according to A. F. Tyulin, are closely related to the dynamics of soil moisture. During periods of high and excessive wetting of the plowed layer, the content of particles and aggregates, cemented by iron humates and serving as the main source for the formation of a water-stable structure, decreases sharply in the soil. The gradual drying of the soil in summer creates conditions for the formation of iron humate aggregates.

2. Biochemical processes taking place in the soil under the influence of plants and related micro-organisms promote the formation of iron humate aggregates. By lowering the oxidation-reduction potential of the soil, the same processes lead to the reduction of iron oxide and its change into soluble ferrous oxide, and, consequently, to the partial disintegration of water-stable aggregates cemented by iron humates.

When the soil is under the influence of perennial legumes – grasses under grass-arable rotation, the synthesis of iron humate aggregates predominates over their decomposition. As a result, the water-stable structure of the soil increases. Conditions are less favorable for aggregation under annual rotation crops.

3. Agricultural melioration practices directed toward the control of the excessive wetting of sod-podzolic clay loam and clay soils must promote the improvement of their structure.

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AGRICULTURAL PHYSICAL PROPERTIES OF LEACHED CHERNOZEMS IN THE TATAR ASSR

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The agricultural physical porperties of soils are one of the most important indices of soil conditions when soil is evaluated as a medium for the development of cultivated plants. However, the soils of the Tatar ASSR have been studied little in this respect. The present paper gives the characteristics of the physical properties of leached chernozems in two agricultural soil regions of the Tatar ASSR: 1) the southwestern Volga region (Stalin kolkhoz and the State Variety Testing Station in Buin rayon) and 2) the western Kama region ("Krasnyy Oktyabr'" and "Druzhba" kolkhozes, Chistopol' rayon), where these chernozems are the main soil fund. All the chernozems, with the exception of Profile 7 in the Chistopol' rayon, are slightly leached (effervescence from 10% HCl in the sub-humus horizon). The soil in Profile 7 does not effervesce in the upper 2 m, i. e., is strongly leached. All the samples were taken in crop rotation fields.

The agricultural-chemical properties of leached chernozems are illustrated in Table 1, which shows that these soils are rich in humus. Its content varies from 7.6% to 8.7%, gradually decreasing with depth. Table 1 also shows that the chernozem from the Buin rayon contain more humus and are thicker than those of the Chistopol' rayon. Their total nitrogen content is also high. The carbon:nitrogen ratio is considerably narrower in the soil of the variety testing station (10.6) than that in the same soil of the kolkhoz field (13.6). The amount of hydrolyzable nitrogen varies from 100-160 mg/kg of soil. The leached chernozem is characterized by a high adsorption capacity, reaching 50-51 meq. The sum of adsorbed cations varies from 46-48 meq. Consequently, its degree of saturation with cations is high. Hydrolytic acidity is insignificant, not exceeding 3.0-3.5 meq. The soil reaction is slightly acid, becoming neutral with depth, except for Profile 7. These soils contain a sufficient amount of available phosphorus (7.3-17.6 mg/100 g of soil) and are rich in available potassium (>25.0 mg/100 g). We can conclude on the basis of Table 1 that the chemical properties of leached chernozems are quite favorable for the development of plants.

The results of particle-size and micro-aggregate determinations of these soils are presented in Table 2. We can easily see from the table that the leached chernozem of the Tatar ASSR are predominantly fine-textured. The texture of Chistopol' chernozems is represented by fine clayey-silty clay loam and that of Buin chernozems, by coarse silty-clayey clay (2, 4). Texture varies little within the profile. However, there is a certain decrease in clay in the lower part of the humus layer and a certain increase in clay in its upper part, as well as in the illuvial horizon of strongly leached soil (Profile 7). Lower down the texture becomes a little coarser.

Table 2 also shows the result of micro-aggregate analysis, made according to the Kachinskiy method (2, 4). The chernozems of the Tatar ASSR are characterized by a well-defined micro-structure. The amount of micro-aggregates >0.25 mm and >0.05 mm in diameter reaches its maximum in the central part of the humus horizon. It decreases noticeably in the plowed horizon and drops sharply with proximity to the parent material (especially particles >0.25 mm in diameter). The amount of microaggregates >0.05 mm in diameter varies from 40% to 57% in the upper horizons of these soils and is higher in the Buin chernozem than in the other chernozems. The amount of the foregoing aggregates varies from 52% to 75% in the central part of the humus layer. The amount of small micro-aggregates (<0.01 mm in diameter) is insignificant; it varies from 10%-16% in the upper horizons. The content of micro-aggregate clay rarely exceeds 2%, being higher only in the lower horizons of the strongly leached chernozem (Profile 7).

The dispersion coefficient, calculated according to the Kachinskiy method (2, 4), is very small. It does not exceed 4% in the plowed layer and occasionally increases to 13%-15% with depth.

We also calculated the micro-structure according to the method of Dimo (1). It proved to be about 26-35 in the upper horizons of leached chernozems. Its comparison with the clay fraction of the texture shows that the latter is almost absent in the structure, except for Profile 7 (strongly leached soil). It must be noted that a calculation of this index for the lower-lying horizons of chernozem soils, in contrast to gray forest and sod-podzolic soils, does not give a clear idea of the participation of the clay fraction in structure formation.

Table 1

Agricultural-chemical properties of leached chernozems (Analyst, L. I. Shitova)

Profile No. and sampling area	Horizon and depth, cm	Humus, %	Nitrogen		C:N	Sum of adsorbed bases[a]	Hydrolytic acidity	Degree of saturation with cations, %	pH		P_2O_5 (accord. to Truog)	K_2O[b] (accrd. to Maslova) means of flame photo
			Total, %	Hydrolyzable, mg/kg of soil		meq/100 g of soil			Saline	Water	mg/100 g of soil	
9. Stalin kolkhoz, Buin rayon	A_p 0—29	7,98	Not det'd.	101,0	—	47,32	2,81	94	5,72	6,85	9,4	25,2
	A_1 29—46	6,24	"	86,6	—	44,84	1,10	98	5,63	6,88	10,8	Not det'd.
	AB 46—59	4,93	"	85,7	—	43,88	0,65	98	5,76	6,82	12,6	"
	B_1 59—70	3,23	"	Not det'd.	—	38,76	0,50	99	5,86	7,04	18,0	"
1. Stalin kolkhoz, Buin rayon	A_p 0—13	8,09	0,34	134,3	13,6	47,60	2,76	95	5,29	6,60	7,3	27,1
	A_p 13—24	7,66	0,28	126,0	15,9	46,52	2,71	94	5,32	6,61	7,4	24,9
	A_1 24—42	6,63	0,26	87,6	14,9	42,12	2,51	94	5,53	6,94	6,1	Not det'd.
	AB 42—59	4,55	0,20	Not det'd.	13,1	37,86	1,10	97	5,93	7,03	7,4	27,1
	B_1 59—81	3,10	0,17	"	10,4		Not det'd.		5,95	7,46	9,8	25,8
3. Buin State Strain Testing Station	A_p 0—13	8,70	0,47	146,7	10,6	43,16	3,42	93	5,30	6,68	9,2	31,3
	A_p 13—22	8,26	0,43	136,3	11,0	46,26	2,71	94	5,39	6,68	9,7	22,4
	A_1 22—38	7,24	0,38	93,7	11,1	45,32	1,86	96	5,60	6,98	6,4	28,7
	AB 38—58	4,74	0,30	Not det'd.	9,2	40,20	0,80	98	5,89	7,03	8,8	24,9
	B_1 58—74	2,62	0,18	"	8,0	35,88	0,50	99	6,38	7,32	9,6	23,0
7. "Krasnyy Oktyabr'" kolkhoz, Chistopol' rayon	A_p 0—20	7,91	Not det'd.		—	43,99	3,07	94	5,15	6,00	17,6	35,1
	A_1 23—33	7,73	"		—	41,23	2,76	93	5,30	6,38	13,8	30,7
	A_1 33—43	6,21	"		—	39,50	2,92	93	5,25	6,31	17,4	31,3
	AB 50—60	3,92	"		—	35,60	2,50	93	5,10	6,32	20,7	31,3
	B_1 65—75	2,50	"		—	30,80	2,41	92	4,90	6,10	29,8	28,7
	B_2 85—95	1,52	"		—	29,64	1,50	95	5,75	6,29	16,8	27,7

Table 1 continued

Profile No. and sampling area	Horizon and depth, cm	Humus, %	Nitrogen		C:N	Sum of adsorbed bases[a]	Hydrolytic acidity	Degree of saturation with cations, %	pH		P_2O_5 (accord. to Truog)	K_2O[b] (acc'rd to Maslova) means of flamephot
			Total, %	Hydrolyzable, mg/kg of soil		meq/100 g of soil			Saline	Water	mg/100 g of soil	
9. "Druzhba" kolkhoz, Chistopol' rayon	A_p 0—22	7,61	Not det'd.	161,0	—	46,33	2,46	95	5,41	5,80	9,0	24,9
	A_1 30—40	4,46	"	158,4	—	40,44	2,40	94	5,67	5,94	8,0	27,7
	AB 40—50	2,98	"	155,4	—	32,76	0,80	97	5,72	6,42	14,0	28,7
	B_1 55—65	1,37	"	Not det'd.	—	29,60	0,55	98	5,98	6,51	23,6	26,5

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[a] The sum of adsorbed cations was determined by the Kappen method as modified by P. V. Madanova and L. M. Voykina.

[b] K_2O was determined by L G. Abyzov at the laboratory of the Kazan' Branch, Academy of Sciences, USSR.

Note: Comma represents decimal point.

This is attributable to the fact that a large amount of micro-aggregates >0.25 mm in diameter is contained in the subplow horizons of chernozems. However, when calculating the micro-structure according to the Dimo method, the given fraction is not taken into account and this index proves to be too low.

The Dimo method of calculating micro-structure gives good results for the entire profile of gray forest soils, which contain a small amount of micro-aggregates >0.25 mm in diameter (5). Calculations of this index are apparently also applicable to the upper plowed horizons of chernozem soils.

As we can see from Table 3, the amount of water-stable aggregates larger than 1 mm in diameter is small in the plowed horizon of leached chernozems (not more than 10%). It increases noticeably in the lower part of the humus horizon and decreases sharply in the parent material. The content of aggregates >0.25 mm in diameter is considerably higher in the Volga chernozems than in the Kama chernozems. Thus, if the plowed layer of the first contains from 32%-41% of these aggregates that of the latter contains from 13%-19%. The same is observed in the subplow layers. The better aggregation of the Volga chernozems is associated with their finer texture, higher humus content, and, apparently, a somewhat different composition of organo-mineral colloids. The extremely small amount of water-stable aggregates larger than 1 mm in diameter in the plowed horizons of leached chernozems indicates that they are significantly dispersed, which is associated with the fact that these soils have been plowed extensively.

Table 4 gives the physical properties of leached chernozems. The particle density of the solid phase is 2.41-2.54 g/cm³ in the upper horizons of these soils, which is associated with their high humus content. It varies from 2.56-2.64 g/cm³ and occasionally reaches 2.74 g/cm³. The bulk density of the plowed horizon of fallow soils (Profile 9, Buin rayon and Profile 9, Chistopol' rayon) is 0.91-0.95 g/cm³, which indicates that they are "fluffy." The bulk density of soils occupied by field crops (rye) or grasses (alfalfa + wheatgrass) reaches 1.21-1.31 g/cm³ (Profile 7, Chistopol' rayon, and Profiles 1 and 3, Buin rayon). This indicates that the soil is very compact, which is due to its insufficient macro-structure and fine texture. The bulk density in the lower horizons varies from 1.3-1.6 g/cm³.

The density or hardness of leached chernozems (their resistance to loosening) does not exceed 8 g/cm² within the profile of these soils which points to the absence of clearly defined illuvial horizons in these soils and is attributable to considerable soil moisture during tillage.

Porosity of the upper horizons of chernozems under fallow reaches 62-64%. This is typical for a cultivated plowed layer. It decreases to 46-60% in the upper horizons of soils under field crops. The decrease in porosity to 46% creates unfavorable conditions for biological processes in these soils. In the lower horizons it decreases to 38-40%, which also confirms that the illuvial process is weak in leached chernozems.

Table 2

Particle-size[a] and micro-aggregate composition of leached chernozems, % of dry soil weight

Profile No. and sampling area	Horizon and thickness, cm		Loss on treatment with HCl[b]	Particle diameter, mm									Disper. coeffic. (accord. to Kachinskiy)	Microstructure (according to Dimo)
				>0,25	0,25–0,05	>0,05	0,05–0,01	>0,01	<0,01	0,01–0,005	0,005–0,001	<0,001		
7. "Krasnyy Oktyabr'" kolkhoz, Chistopol' rayon	Ap	0–23	Not detd.	0,67/18,30	9,08/21,60	9,75/39,90	32,17/45,90	41,92/85,80	58,08/14,20	7,42/8,37	12,08/4,24	38,58/1,59	4,1	26,25
	A_1	23–33	"	0,50/22,79	15,82/35,13	16,32/57,92	33,81/31,59	50,13/89,51	49,87/10,49	8,80/4,61	8,26/4,40	32,81/1,48	4,5	—
	A_1^1	33–44	"	0,55/18,55	13,59/34,02	14,14/52,57	32,97/34,03	47,11/86,60	52,89/13,40	8,32/5,56	12,77/4,56	31,80/3,28	10,3	—
	AB	44–61	"	0,59/14,29	11,58/28,74	12,17/43,03	34,18/40,74	46,35/83,77	53,65/16,23	6,25/6,40	11,60/5,98	35,80/3,85	10,8	—
	B_1	61–77	"	0,68/14,69	12,49/30,92	13,17/45,61	33,28/37,33	46,45/82,94	53,55/17,06	5,88/7,14	11,34/5,51	36,33/4,41	12,1	—
	B_2	77–103	"	0,86/21,81	9,80/27,59	10,66/49,40	36,00/34,08	46,66/83,48	53,34/16,52	7,33/6,47	10,97/6,95	35,04/3,10	9,0	—
	B_3	103–150	"	0,60/9,83	13,41/25,39	14,01/35,22	33,44/44,41	47,45/79,63	52,55/20,37	7,77/4,93	7,87/10,45	36,91/4,99	13,5	
	BC	150–200	"	1,54/5,75	19,71/35,77	21,25/41,52	25,41/37,75	46,66/79,27	53,34/20,73	5,46/6,98	10,50/8,08	37,38/5,67	15,2	—
3. Buin State Strain Testing Station	Ap	0–13	Not detd.	0.54/17,17	2,58/39,59	3,12/57,29	35,51/32,75	38,63/90,04	61,37/9,96	10,44/4,72	13,78/4,82	37,15/0,42	1,1	34,25
	Ap	13–22	"	0,45/13,30	2,03/33,43	2,48/46,73	37,47/41,45	39,95/88,18	60,05/11,82	8,85/6,09	13,04/5,03	38,16/0,70	1,8	35,38
	A_1	22–38	"	0,33/38,10	3,74/30,98	4,07/69,08	37,66/24,23	41,73/93,31	58,27/6,69	6,31/1,39	16,96/4,12	35,00/1,18	3,4	—
	AB	38–58	"	0,31/20,88	5,99/54,38	6,30/75,26	33,92/16,11	40,22/91,37	59,78/8,63	9,52/2,54	10,60/4,77	39,66/1,32	3,3	—

Table 2 continued

Profile No. and sampling area	Horizon and thickness, cm	Loss on treatment with HCl[b]	Particle diameter, mm									Disper. coeffic. (accord. to Kachinskiy)	Micro-structure (according to Dimo)
			>0,25	0,25—0,05	>0,05	0,05—0,01	>0,01	<0,01	0,01—0,005	0,05—0,001	<0.001		
	B$_1$ 58—74	Not det'd	0,30 21,67	8,70 40,22	9,00 61,89	31,80 27,93	40,80 89,82	59,20 10,18	11,50 4,35	11,02 4,40	36,08 1,43	3,9	—
	B$_2$ 74—94	9,73	0,51 19,59	4,50 47,03	5,01 66,62	35,43 20,58	50,13 87,20	49,87 12,80	10,56 4,67	6,42 7,66	32,85 0,47	1,4	—
	B$_3$ 94—122	13,08	0,30 7,35	2,36 51,24	2,66 58,59	26,37 28,87	42,11 87,46	57,89 12,54	18,49 5,56	9,87 4,67	29,53 2,31	7,8	—
	BC 122—150	6,11	0,37 2,86	4,28 23,31	4,65 26,17	44,75 63,91	55,51 90,08	44,49 9,92	8,90 2,96	5,52 5,77	30,70 1,19	3,9	—
9. "Druzhba" kolkhoz, Chistopol' rayon	A$_p$ 0—27	Not det'd.	0,81 13,32	10,94 36,08	11,75 49,40	31,43 38,05	43,18 87,45	56,82 12,55	9,38 4,29	11,29 7,84	36,15 0,42	1,2	31,76
	A$_1$ 27—44	"	1,09 34,93	11,05 22,38	12,14 57,31	31,85 28,94	43,99 86,25	56,01 13,75	7,84 5,51	10,86 5,56	37,31 2,68	7,2	—
	AB 44—50	"	0,76 34,01	4,33 25,73	5,09 59,74	36,85 28,72	41,94 88,46	58,06 11,54	8,24 4,30	11,13 6,14	38,69 1,10	2,8	—
	B$_1$ 50—69	"	0,73 19,62	12,49 23,38	13,22 43,00	29,35 40,63	42,57 88,63	57,43 16,37	9,45 5,98	3,36 7,87	44,42 2,52	5,7	—
	B$_2$ 69—86	"	0,52 7,59	19,09 28,87	19,61 36,46	30,47 45,34	50,08 81,80	49,92 18,20	7,54 12,06	9,93 5,98	32,45 0,16	0,5	—
	BC 86—150	17,55	1,71 11,48	1,03 28,25	2,74 39,73	32,99 42,59	53,28 82,32	46,72 17,68	6,55 8,53	6,86 8,16	33,31 0,99	3,0	—
	C 150—180	11,6	5,14 4,28	22,64 37,17	27,78 41,45	10,94 42,74	49,48 84,19	50,52 15,81	6,07 8,27	20,26 6,50	33,79 1,04	3,1	—

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[a] The particle-size analysis was made by L. I. Shitova.

[b] The loss on treatment with HCl was included by us in the sum of 100% as a "miscellaneous" fraction (4).

Note: Comma represents decimal point.

Table 3

Aggregate composition of leached chernozems, % of dry sample

Profile No. and sampling area	Horizon and depth, cm	Aggregate diameter, mm			Profile No. and sampling area	Horizon and depth, cm	Aggregate diameter, mm		
		>1	>0,25	<0,25			>1	>0,25	<0,25
7. "Krasnyy Oktyabr'" kolkhoz, Chistopol' rayon	A_p 0—20	1,6	13,5	86,5	1. Stalin kolkhoz, Buin rayon	A_p 0—14	11,2	41,6	58,4
	A_1 23—33	7,1	47,1	52,9		A_p 14—24	5,3	41,7	58,3
	A_1 33—43	22,8	52,3	47,7		A_1 24—42	45,8	80,2	19,8
	AB 50—60	29,9	59,4	40,6		AB 42—59	43,3	80,6	19,4
	B_1 65—75	15,5	58,4	41,6		B_1 59—81	27,8	66,2	33,8
	B_3 120—130	2,3	20,2	79,8		B_2 81—102	13,1	30,7	69,3
	BC 180—190	4,1	41,6	58,4		B_3 102—120	20,4	42,1	57,9
						BC 135—145	12,8	47,1	52,9
9. "Duruzhba" kolkhoz, Chistopol' rayon	Ap 0—22	4,2	18,9	81,1	Same	Ap 0—29	4,0	31,7	68,3
	A_1 30—40	30,0	38,7	61,3		A_1 29—46	16,3	68,3	31,7
	AB 45—50	26,1	37,4	62,6		AB 46—59	25,0	78,4	21,6
	B_1 55—65	40,6	74,2	25,8		B_1 59—70	35,7	58,5	41,5
	B_2 73—83	19,3	53,1	46,9		B_2 83—93	17,3	52,4	47,6
	BC 147—157	15,3	48,8	51,3		B_3 115—125	14,9	40,7	59,3
	C 180—190	0,9	19,1	80,9		BC 140—150	0,4	3,7	96,3

Note: Comma represents decimal point.

From 30-40% of the total pore volume in the upper horizons is occupied by capillary water. The volume of such pores decreases very sharply in the illuvial horizon of certain soils (Profiles 1, 7). The fact that a considerable portion of the pores in leached chernozems is occupied by strongly and loosely bound water is an unfavorable condition. The total volume of these pores, starting with the upper horizon, varies from 20%-40% along the entire profile, which is attributable to the fine texture and high humus content of these soils.

In contrast to light-gray forest soils (5), a considerable portion of the pores in leached chernozems is occupied by air with capillaries saturated with water. The volume of aeration pores in soils under field crops is about 30% in the upper horizons. It increases to 50%-60% in fallow soils. The large amount of aeration pores in leached chernozems creates favorable conditions in them for microbiological and biochemical processes. This is the reason for the large accumulation of humus in the profile of these soils. The volume of aeration pores is large throughout the profile to a depth of 1.5-2.0 m.

As we can see from Table 5, leached chernozems have a high water-holding capacity. The full water capacity of the upper horizons is 47%-57% and evenly decreases with depth as a result of the decrease in humus. The capillary water capacity of these soils is also high. It varies from 32%-38% in the upper horizons and also decreases with depth. The relationship between full and capillary moisture capacity in the plowed layer is such that the latter amounts to 63%-73% of the former, increasing to 85% in the lower part of the profile. Such a relationship between water capacities is rather favorable; it points to the presence of both capillary and non-capillary porosity (the ratio between them is about 3:1, 2:1) in the upper horizons of leached chernozems.

The negative properties of leached chernozems include their very high maximum hygroscopicity, which is associated with their fine texture, and their high humus content. Maximum hygroscopicity varies most often between 12%-14% and only occasionally drops to 10%. The result of this is the fact that leached chernozems retain a large amount of moisture which is practically unavailable to plants. This is confirmed by the wilting moisture content of plants. It is very high, varying from 18%-20%. Consequently, moisture is often unproductive, even at an absolute soil moisture content of about 20%. This is why the "range of active moisture" (3) is insufficient. It varies from 13%-20% in the upper horizons and decreases sharply in the illuvial horizons.

Having a high water capacity, the leached chernozems of the Tatar ASSR retain a large amount of water which reaches 500-600 mm in the upper 1.5 mm layer and exceeds 700 mm in the upper 2 m layer. However, only 39%-50% and sometimes 25% (Profile 7) of this water is available to plants.

Table 4

Physical properties of leached chernozems

Profile No. and sampling site	Horizon and depth, cm	Particle density	Bulk density, g/cm³	Hardness, kg/cm²	Porosity					
					Total, %	Pore volume, % of total porosity, occupied by				
						water				By air capil. satura. with water
						Capillary	Loosely bound	Strongly bound	Total	
1. Stalin kolkhoz, Buin rayon	A_p 0—14	2,45	1,31	6,00	46,5	42,2	15,3	25,6	83,1	16,9
	A_p 14—24	2,48	1,09	4,13	56,1	33,5	10,9	18,0	62,4	37,6
	A_1 24—42	2,47	1,09	5,33	55,9	27,5	11,3	18,8	57,6	42,4
	AB 42—59	2,51	1,19	5,20	52,6	16,9	13,1	23,8	53,8	46,2
	B_2 81—102	2,53	1,30	6,00	48,2	37,8	13,3	22,2	73,3	26,7
	B_3 102—120	2,56	1,29	5,60	49,6	27,8	12,9	21,3	62,0	38,0
	BC 135—145	2,56	1,47	6,66	42,6	21,1	15,7	26,3	63,1	36,9
9. Stalin kolkhoz, Buin rayon	A_p 0—29	2,54	0,91	Very friable	64,2	29,3	6,7	11,1	47,1	52,9
	A_1 29—46	2,59	1,16	4,13	55,2	47,8	10,5	17,2	75,5	24,5
	AB 46—59	2,65	1,13	4,53	57,4	36,2	9,4	15,7	61,3	38,7
	B_1 59—70	2,65	1,21	4,53	54,3	24,1	10,1	17,3	51,5	48,5
	B_2 85—95	2,68	1,33	4,40	50,0	31,4	12,0	20,4	63,8	36,2
	B_3 115—125	2,73	1,31	5,86	52,0	35,0	10,2	17,1	62,3	37,7
	BC 140—150	2,74	1,46	5,66	46,7	77,1	8,5	14,4	100,0	--
3. Buin state strain testing station	A_p 0—13	2,41	1,21	6,00	49,8	31,7	14,1	23,1	68,9	31,1
	A_p 13—22	2,43	1,19	7,60	51,0	21,2	13,7	23,1	58,0	42,0
	A_1 22—38	2,55	1,17	3,06	54,1	26,8	12,4	20,7	59,9	40,1
	AB 38—58	2,50	1,22	6,53	51,2	35,3	11,9	20,1	67,3	32,7
	B_1 58—74	2,61	1,23	7,06	52,9	34,2	11,7	19,7	65,6	34,4
	B_2 80—90	2,61	1,24	7,06	52,5	40,6	10,7	17,9	69,2	30,8
	B_3 104—114	2,55	1,36	7,06	46,7	51,8	12,8	23,3	87,9	12,1
	BC 148—158	2,58	1,41	6,26	45,4	33,4	13,6	22,9	69,9	30,1
7. Kolkhoz "Kpasnyy Oktyabr'" Chistopol' rayon	A_p 0—20	2,49	1,16	5,20	53,4	35,4	10,7	17,8	63,9	36,1
	A_1 23—33	2,50	1,09	4,80	56,4	24,5	9,6	15,8	49,9	50,1
	A_1^1 33—43	2,58	1,12	4,53	56,6	22,1	9,9	16,6	48,6	51,4
	AB 50—68	2,56	1,27	5,33	50,0	11,2	12,0	20,0	43,2	56,8
	B_1 65—75	2,59	1,39	5,86	46,4	9,1	14,9	24,8	48,8	51,2
	B_2 85—95	2,58	1,48	5,73	42,7	7,2	16,4	27,6	51,2	48,8
	B_3 120—130	2,57	1,60	5,60	37,8	20,6	20,6	34,6	75,8	24,2
	BC 190—200	2,59	1,54	3,73	40,0	10,5	19,0	32,0	61,5	38,5
9. Kolkhoz "Dryzhba," Chistopol' rayon	A_p 0—22	2,52	0,95	0,13	62,3	19,3	7,8	13,2	40,3	59,7
	A_1 30—40	2,53	1,28	4,26	51,3	25,1	14,0	23,2	72,3	27,7
	AB 44—50	2,56	1,40	4,53	45,4	32,5	16,1	26,6	75,2	24,8
	B_1 55—65	2,64	1,41	4,53	46,3	45,3	12,1	20,5	77,9	22,1
	B_2 73—83	2,61	1,45	3,42	44,4	29,7	13,5	22,2	65,7	34,3
	BC 147—157	2,58	1,60	4,53	38,0	40,4	15,7	26,3	82,0	18,0
	C 170—180	2,58	1,46	3,33	43,4	29,2	13,8	23,0	66,0	34,0

Note: Comma represents decimal point.

Table 5

Hydrological properties of leached chernozem

Profile No. and sampling site	Horizon and depth, cm	Water capacity, %			Maximum hygroscopicity	Wilting coefficient	Range of active moisture	Amount of water held by the soil, mm					
		Total	Capillary	Capillary from total				Total			Active		
								By horizon	In the layer from 1–1.5–2 m		By horizon	In the layer from 1–1.5–2 m	
1. Stalin kolkhoz, Buin rayon	A$_p$ 0—14	56,6	35,5	63	13,69	20,5	15,0	65,1	392,0	552,0	27,5	129,1	180,6
	A$_p$ 14—24	52,8	38,3	72	13,99	21,0	17,3	41,7			18,8		
	A$_1$ 24—42	47,0	35,7	76	14,43	21,6	14,1	70,0			16,8		
	AB 42—59	54,1	31,0	57	15,72	23,5	7,5	63,7			15,1		
	B$_1$ 59—81	32,8	25,2	77	13,03	19,5	5,7	66,0			14,9		
	B$_1$ 81—102	38,3	31,8	83	12,42	18,6	13,2	85,5			36,0		
	B$_3$ 102—120	34,5	29,2	85	12,38	18,6	10,6	67,8	160,5		24,6	51,5	
	BC 120—150	27,8	23,3	84	11,46	17,2	6,1	92,7			26,9		
9. Same	A$_p$ 0—29	52,5	38,4	73	11,77	17,7	20,7	101,3	379,4	572,1	54,6	188,0	287,4
	A$_1$ 29—46	59,0	41,2	70	12,34	18,4	22,8	81,2			44,9		
	AB 46—59	41,3	36,4	88	11,97	18,0	18,4	43,5			27,0		
	B$_1$ 59—70	35,9	28,3	80	11,67	17,5	10,8	37,7			14,4		
	B$_2$ 70—115	35,4	29,0	82	11,53	17,2	11,8	115,7			47,1		
	B$_3$ 115—125	34,7	29,2	84	10,17	15,3	13,9	96,0	192,7		41,7	99,4	
	BC 125—150	32,0	26,3	82	6,94	10,5	15,8	96,7			57,7		
3. Buin state strain testing station	A$_p$ 0—13	47,0	34,5	73	14,34	21,4	13,1	54,3	405,3	615,7	20,6	172,0	268,8
	A$_p$ 3—22	45,8	31,4	68	14,89	22,3	9,1	33,6			9,7		
	A$_1$ 22—38	45,8	34,0	74	14,39	21,6	12,4	58,2			21,2		
	AB 38—58	43,1	33,8	78	12,70	19,0	14,8	82,5			36,1		
	B$_1$ 58—74	41,5	33,6	81	12,64	18,9	14,7	66,1			28,9		
	B$_2$ 74—94	43,3	34,3	80	11,41	17,1	17,2	110,6			55,5		
	B$_3$ 94—122	40,9	34,3	84	10,98	16,5	17,8	102,6	210,4		53,2	96,8	
	BC 122—150	30,2	27,3	90	11,04	16,5	10,8	107,8			43,6		

Table 5 continued

Profile No. and sampling site	Horizon	Depth, cm	Water capacity, %			Maximum hygroscopicity	Wilting coefficient	Range of active moisture	Amount of water held by the soil, mm			
			Total	Capillary	Capillary from total				Total: By horizon	Total: In the layer from 1-1.5-2[a] m	Active: By horizon	Active: In the layer from 1-1.5-2[a] m
7. Kolkhoz "Krashyy Oktyabr'", Chistopol rayon	Ap	0—29	49,2	34,7	70	12,25	18,4	16,3	92,6		43,5	
	A_1	23—33	47,6	31,3	66	12,37	18,5	12,7	34,1		13,8	
	A_1^1	33—44	46,2	30,2	65	12,65	19,0	11,2	37,2	327,8	13,8	94,6
	AB	44—61	37,2	22,1	59	11,82	17,7	4,4	47,7	514,2 679,0	9,6	133,8 154,6
	B_1	61—77	29,7	21,5	72	12,36	18,5	3,0	47,8		6,7	
	B_2	77—103	28,0	20,1	72	12,00	18,0	2,1	68,4		7,2	
	B_3	103—150	26,7	23,3	87	12,23	18,4	4,9	186,4	186,4	39,2	39,2
	BC	150—200	30,0	21,4	71	12,49	18,7	2,7	164,8	164,8	20,8	20,8
9. Kolkhoz "Druzhba," Chistopol' rayon	Ap	0—27	48,0	32,0	67	12,93	19,4	12,6	82,1		32,3	
	A_1	27—44	47,3	31,1	66	13,95	21,0	10,1	67,7		23,0	
	AB	44—50	45,0	30,0	67	12,95	19,4	10,6	25,2	367,0	8,9	
	B_1	50—69	44,5	30,0	67	10,07	15,1	14,9	80,4	555,8 731,7	33,9	141,7 217,7 291,2
	B_2	69—86	28,3	24,7	87	10,39	15,6	9,1	111,6		43,6	
	BC	86—150	28,4	23,6	83	9,4	14,1	9,5	188,8	188,8	76,0	76,0
	C	150—200	25,1	24,1	85	10,29	15,4	8,7	175,9	175,9	63,5	63,5

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[a] The wilting coefficient was calculated from 1.5 maximum hygroscopicity.

Note: Comma represents decimal point.

Conclusions

1. Leached chernozems have good agricultural-chemical properties: they are rich in humus, nitrogen (total and available), adsorbed bases, available potassium and phosphorus, and have a weakly acid reaction.

2. The physical properties of leached chernozems are somewhat less favorable. Having a sufficiently good micro-structure, friability, good porosity and aeration, and a high water-holding capacity, these soils are very dispersed in the top horizons. The dispersiveness of the plowed layer is accompanied by its compaction, which decreases the water permeability and increases the evaporability of these soils, and, consequently, leads to a decrease of their moisture content.

Leached chernozems have a very high capacity to retain water in a bound state (strongly and loosely), which results in a sharp decrease of the range of active moisture in them. Because of these reasons the yield of field crops drops sharply on leached chernozems, especially in years with an early spring drought.

3. To improve the physical properties of leached chernozems and to ensure productive moisture for the crops grown on them we must:

a) plow the soil deeply in the fall. Best results should be obtained by plowing the sod under, since it would improve the structure of the upper dispersed horizons and control their dispersion;

b) establish forest shelterbelts on them, which would promote even snow distribution, alleviate the drying force of winds, and protect the soil from flowing.

c) organize basin irrigation on them to utilize more fully meltwater;

d) introduce crop rotation to control erosion on leached chernozems in areas subject to erosion.

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COMPARATIVE CHARACTERIZATION OF THE COMPOSITION OF SOLUTIONS AND LYSIMETRIC WATERS OF STRONGLY PODZOLIC SOIL FROM AN OXALIS SPRUCE FOREST

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Certain progress has been made in recent years in the study of the composition and properties of soil solutions. Original methods of extracting solutions from the soil have been worked out and introduced into the practice of soil chemistry investigations. The improved method of Kryukov (2) for squeezing solutions from soil samples by means of a special hydraulic press has been widely accepted. The method developed by Komarova (1) of extracting a soil solution by displacing it with ethyl alcohol in plastic or glass tubes shows great promise. We used the lysimetric method (4) for extracting soil solutions from non-disturbed soil under natural conditions.

These methods differ greatly from each other. The method of squeezing solutions from the soil, as well as the method of displacing a solution with ethyl alcohol are used on soil samples in equilibrium with atmospheric air, having an insignificant amount of carbon dioxide and water vapor. Under such conditions there is always a danger that the soil samples will loose carbon dioxide and water vapor, which would reflect on the other components of the solution.

The lysimetric method is used on soils under natural conditions and therefore does not disturb their inherent equilibrium. But this method can only be used when the moisture content of the soil is high, when the non-capillary soil interstices are filled with gravitational water so that the oxidation-reduction equilibrium tends toward the formation of not fully oxidized organic and mineral compounds, while the acid-base equilibrium is characterized by an increase in the partial pressure of CO_2 and the concentration of bicarbonate salts.

The methods of separation and the dynamics of the conditions of formation of soil solutions make it necessary to study them comparatively: this would make it possible on the one hand to evaluate objectively the methods themselves and their applicability, and on the other hand to determine properties of the solutions under various conditions and thus define their role in soil formation and fertility conditions.

The present paper describes the results of investigations on the composition of soil solutions, obtained by the three methods mentioned earlier.

1. The displacement of the soil solution by ethyl alcohol in glass tubes 120 cm long and 2.0 cm in diameter (called the displacement method).

2. The squeezing-out of the solution with a press at a pressure of 181 kg/cm² (called the squeezing method).

3. By the lysimeters applied to non-disturbed soils (called the lysimetric method).

All methods were used as they were recommended by their authors.

Because of the small volume of solution obtained and the necessity of thoroughly investigating the solutions, the accuracy and speed of chemical analysis are of utmost importance. The following method was adopted after preliminary verification.

The total concentration of the solution and of the SO_4^{--} was determined in a single sample. To do this 2-5 ml of the solution were evaporated in calibrated platinum 10 ml crucibles, then the dry residue was dried for 3 hrs at a temperature of 105°C and weighed. The total dry residue and half of the HCO_3^- in the solution served as the index for the total concentration of the solution. The content of the dish was treated with 10% HCl after ignition, dried, dissolved in a small amount of hot 1% HCl, and filtered through a thick filter into a calibrated 10-ml test tube, the filter being washed with small amounts of the same acid. The volume of liquid in the test tube was brought to 9 ml, 5 drops of 8% $Ba(NO_3)_2$ were added, and then the tube was brought to volume with water. The turbidity of the contents of the test tube was then compared with the scale of standard solutions with an SO_4^{--} concentration in the range from 0-20 mg/liter (3).

The total Ca^{++} and Mg^{++} was determined by titration from the black chromogen in a solution (1-2 ml) of 0.01 N trilon, double dilution with distilled water. The Ca^{++} was determined with the same trilon solution using murexide as an indicator. The micro-burettes used in the analysis permitted readings of up to 0.005 ml. Consequently, when titrating a 1-2 ml solution its Ca^{++} concentration must not be less than 1.0-0.5 mg/liter and its magnesium concentration not less than 0.6-0.3 mg/liter. The HCO_3^-

Table 1

Composition of solutions and lysimetric waters from strongly podzolic soil

Horizon	Depth of sampling	Moisture,%		Solution obtained		Dry residue, mg/liter	pH	Acidity, meq/liter		Mg/liter		
		of absolutely dry soil	of capillary moist. cap.	ml	% of its content in soil			from CO_2	From non-volatile acids	Ca^{++}	Mg^{++}	$K^+ + Na^+$
Solutions extracted by the displacement method October 26, 1959												
A_0	0—5	92,7	68,5	49	Not det'd.	1640	6,0	0,20	1,12	63,4	7,5	None
A_1	7—12	20,6	63,4	38	48,0	670	6,3	0,28	0,11	21,0	4,6	"
A_2	15—25	11,7	66,5	20	65,8	160	5,3	0,22	0,15	2,8	1,7	16,5
A_2B	45—55	12,0	98,4	13	52,0	162	6,2	Not det'd.		3,8	3,9	10,5
B	70—80	10,9	97,8	12	51,3	220	6,1	0,11	0,00	5,8	1,7	13,2
Solutions extracted by the squeezing method												
A_0	0—5	92,7	68,5	39	Not det'd.	1190	5,9	0,33	1,21	46,0	8,6	None
A_1	7—12	20,6	63,4	41	"	340	5,5	0,27	0,39	16,2	3,5	1,7
A_2	20—25	11,7	66,5		"	Solutions were not extracted from this horizon and below						
Lysimetric waters												
A_0	5	Not det'd.		1545		427	6,0	0,60	0,61	25,2	11,8	None
A_1	17	"			Solutions did not penetr. into the lysimeter in autumn							
A_2	25	"		40		Not det'd.				8,4	5,9	3,2
A_2B	55	"		2500	—	234	5,7	1,02	0,00	12,2	6,2	5,0
B	80	"		50	—	Not det'd.	7,0	1,84	0,00	36,2	32,0	7,0
Solutions extracted by the displacement method October 26, 1959												
A_0	0—5	102,8	—	76,0	73,0	1075	5,3	0,22	0,66	29,4	12,9	Not det'd.
A_1	7—12	26,8	—	39,7	81,5	683	4,9	0,11	0,66	7,8	4,7	8,2
A_2	15—25	21,3	—	26,5	75,7	129	4,9	0,00	0,22	3,9	2,8	6,2
A_2B	45—55	15,1	—	5,5	19,9	Not det'd.	4,9	Not det'd.		6,8	7,6	12,2
B	70—80	11,8	—	4,3	21,5	"	5,5	0,1	0,22	9,8	6,4	Not det'd.
Solutions extracted by the squeezing method												
A_0	0—5	102,8	—	52,0	50,0	933	4,9	0,33	0,77	20,6	14,1	Not det'd.
A_1	7—12	26,8	—	21,0	33,1	462	5,8	0,22	0,33	8,8	5,3	13,0
A_2	15—25	21,3	—	16,5	31,2	Not det'd.	5,5	0,22	0,22	5,9	2,3	14,8
A_2B	45—55	15,1	—		The solution was not squeezed out							
Lysimetric waters												
A_0	5	Not det'd.	—	2200	Not det'd.	350	5,9	0,82	1,06	27,8	12,0	None
A_1	17	"	—	2100	"	152	6,6	1,04	0,20	13,0	6,9	7,0
A_2	25	"	—	2200	"	94,0	5,7	1,17	0,13	10,2	3,7	3,2
A_2B	55	"	—	5000	"	146,0	6,5	0,84	0,00	11,0	6,8	None
B	80	"	—	400	"	180,0	6,9	1,08	0,00	20,0	12,5	0,5

Note: Comma represents decimal point.

was determined by titrating 1-5 ml of the solution with 0.02 N H_2SO_4. The Cl^{-} was determined by titrating the same amount of solution with a 0.02 N solution of $AgNO_3$. The alkali (K + Na + NH_4) and anions of organic acids were calculated by difference, which naturally does not give the right idea of their content, especially in the upper horizons where both are present. But since this method allows the control of the results of the entire analysis, its use is very expedient. Total acidity and the acidity from non-volatile acids were

Table 1 continued

mg/liter				% eq							$\frac{Ca^{++}}{Mg^{++}}$	$\frac{SO_4^=}{Cl^-}$	Dry residue $\frac{\frac{1}{2}, HCO_3^-}{\Sigma \text{ ions}}$
HCO_3^-	$SO_4^=$	Cl^-	Σ ions	Ca^{++}	Mg^{++}	K^++Na^+	HCO_3^-	$SO_4^=$	Cl^-	Organic acids			
76,8	85,0	20,2	252,9	41,8	8,2	None	16,6	23,4	7,5	2,5	8,4	4,2	6,6
36,6	33,0	8,5	103,7	34,4	12,4	3,2	19,6	22,6	7,8	None	4,5	3,9	6,6
10,3	25,0	8,9	65,2	7,5	7,5	35,0	9,1	27,6	13,3	"	1,6	2,8	2,5
11,6	25,0	8,2	63,0	10,1	17,6	22,3	10,1	27,6	12,3	"	0,98	3,0	2,6
8,9	30,0	6,7	66,3	15,1	7,3	27,6	7,3	32,8	9,9	"	3,4	4,4	3,5
68,4	43,2	16,7	182,9	38,1	11,9	None	18,6	14,9	7,8	8,7	5,3	2,6	6,7
19,5	25,0	11,7	77,6	34,6	12,4	3,0	13,7	22,2	14,1	None	4,6	2,1	4,5
65,1	25,0	3,0	130,1	28,2	21,8	None	23,9	11,6	1,8	12,7	2,1	8,3	3,5
21,9	29,0	3,0	71,4	20,2	23,5	6,3	17,3	28,8	3,9	None	1,4	9,7	—
31,4	33,4	3,6	91,9	23,3	19,4	7,3	19,5	26,7	3,8	"	1,9	9,3	2,5
183,0	75,0	6,8	340,0	19,1	28,0	2,9	31,6	16,4	2,0	"	1,1	11,0	—
23,7	33,0	9,9	108,9	28,8	21,2	None	7,6	13,5	5,4	23,5	2,3	3,3	10,0
5,9	35,0	9,9	71,5	17,6	17,6	14,8	4,5	32,9	12,6	None	1,7	3,5	9,7
3,5	19,0	13,2	48,6	11,3	13,7	25,0	3,6	23,8	22,6	"	1,4	1,4	2,7
5,9	30,0	29,1	88,9	11,6	21,4	17,0	3,4	21,1	25,5	"	0,9	1,2	—
5,9	—	—	—	—	—	—	—	—	—	"	—	—	—
11,8	37,5	13,2	97,2	23,4	26,6	None	4,3	17,8	8,6	19,3	1,7	2,8	9,6
18,2	35,0	13,2	93,5	15,6	15,6	18,8	10,6	25,9	13,5	None	1,7	2,7	5,0
11,8	20,0	16,5	71,3	13,4	9,3	27,3	8,9	19,4	21,7	"	2,5	1,2	—
26,2	55,0	3,9	124,9	29,1	20,9	None	9,0	23,9	2,3	14,8	2,3	14,1	2,9
34,2	40,0	3,9	105,0	21,6	19,0	9,4	18,7	27,6	3,7	None	1,9	10,2	1,6
23,8	20,0	5,3	66,2	26,3	16,3	6,8	20,5	21,5	8,0	"	2,7	3,8	1,6
34,2	21,0	4,3	77,3	24,5	25,4	None	25,0	19,5	5,4	"	1,6	4,9	2,1
87,4	25,0	3,9	149,3	24,3	25,2	0,5	34,7	12,6	2,7	"	1,6	6,4	1,5

determined by titrating 2-5 ml of the solution with 0.02 N NaOH before and after boiling for 3 min. The pH was measured electrometrically with glass electrodes in 0.5-1.0 ml of the solution.

The soil under investigation was strongly podzolic virgin soil from an oxalis spruce forest (Siver experimental forest, Leningrad Oblast'). The description of the morphological and chemical properties of the soil was given in earlier publications (4, 6). Soil samples for the extraction of solutions and samples of lysimetric water were taken on October 26, 1959, and May 9, 1960. The analytical data are presented in Table 1.

The results indicate that all three methods give the amount of solution necessary for analysis and are applicable to the study of its qualitative composition. We must note, however, that in all cases the displacement of the solution with ethyl alcohol in a sample diluted with sand ensured the more full removal of the liquid phase than the squeezing method. Because of the high dehydrating capacity of alcohol, the displacement method makes it possible to obtain solutions from the entire profile throughout the year, provided the soil samples are sufficiently diluted with sand; this is the great advantage of this method. The squeezing method, without the additional action of alcohol, is very effective when working with litter and humus horizons, which have a high water capacity and an insignificant compressive strength. The power of our press proved insufficient for removing solutions from mineral horizons, which have a very low water capacity and do not subject to compression, so that we were unable to obtain them in spite of the fact that the relative moisture of this part of the profile was close to capillary moisture capacity.

The lysimetric method makes it possible to obtain large amounts of solutions from all the horizons, especially during the period of spring wetting. Autumn waters penetrate the lysimeter irregularly, often in limited amounts, and very unevenly along the profile. The water penetrates through root channels and cracks more rapidly and in larger amounts into the lower horizons than into the upper, as was the case in the A_2B horizon. This problem is discussed in more detail in another paper (6).

The qualitative composition of solutions corresponds to the conditions of formation and the peculiarities of the methods of separation. The data in Table 1 show that the solutions obtained by the displacement and squeezing methods do not differ essentially from each other. Values are similar in concentration, composition, and ratio between the major components. Lysimetric waters obtained under natural conditions differ from them considerably, as was to be expected. The composition of the latter differs greatly along the profile and from season to season. Therefore, it is expedient to examine them in more detail.

Litter solutions. Forming under conditions of a regular supply of plant residue and the intense development of biological processes, litter solutions are characterized by the highest total concentration and a wide dry residue + 1/2 HCO_3^-/Σ ions ratio. This feature is found under all methods of separation both in autumn and spring samples. At the same time, as we can see from Table 1, the amount of dry residue is clearly related to the methods of solution separation. When the solutions are extracted with ethyl alcohol or under pressure, the amount of solid residue is the largest and sharply decreases in the lysimetric solutions, diluted by atmospheric water. There is a great difference in the qualitative composition of these solutions, which is evidenced by the difference in the dry residue + 1/2 HCO_3^-/Σ ions ratio, which is wide in the first two and considerably narrower in the second.

The seasonal variations in the total and, especially, ion concentration are reflected differently in the solutions. The amount of dry residue decreases from autumn to spring by 34% and 21%, respectively, in the solutions obtained by the displacement and squeezing methods, while it decreases by 18% in lysimetric solutions. The total ions in the first two solutions decreases respectively by 57% and 47% during the same period, while in the latter it decreases only by 4%. The ion concentration is solutions extracted from the solid phase reached 252.9-182.9 mg/liter in autumn, while in lysimetric solutions it was 130.1 mg/liter. The relation between these values reversed during the spring, after the prolonged interaction between the litter and winter-spring melt water and its intense leaching. The ion concentration dropped to 108.9 and 97.2 mg/liter in solutions extracted by alcohol and under pressure, and became lower than in the lysimetric water, where it also decreased, but only to 124.9 mg/liter. The dry residue + 1/2 HCO_3^-/Σ ions ratio changed correspondingly. It was 6.6 and 7.1 in autumn and increased to 10.1 and 9.6 in spring in the first two solutions, while in the latter it decreased during the same period from 3.5 to 2.9. Consequently, the qualitative composition of solutions obtained from the litter by the displacement and squeezing methods, on the one hand, and by the lysimetric method, on the other, changed in opposite directions from the autumn of 1959 to the spring of 1960. The first lost the mineral elements they contained, while the latter became enriched in them.

The most intensely migrating element is the calcium ion. Autumn solutions, extracted by the displacement and squeezing methods, contained about twice as much calcium as the lysimetric waters, while in spring its concentration in the former decreased by half, while it increased slightly in the latter. As a result, a spring solution contained approximately the same amount of calcium.

The magnesium ion, as the calcium ion, actively participates in biochemical processes, which is evidenced by its accumulation in litter solutions. But, because of the insignificant amount of magnesium in the ash of woody plants and, especially, in the litter, its concentration and relative participation in the salt composition of the solutions are considerably smaller than those of calcium. In contrast to all other ions, magnesium concentration is at a maximum, not in autumn solutions formed under the participation of fresh litter, but in spring solutions, interacting with highly decomposed litter. The distribution of Mg^{++} by types of solution is very unusual. In autumn it seems to move into lysimetric waters, where its concentration is higher than in the solutions obtained by the displacement and squeezing methods. Such a behavior of magnesium can have various reasons: by its relatively high mobility, and by its special physiological functions, associated with the life activity not only of higher plants, but also by sporophytes, in particular mosses in whose ash composition magnesium occupies a prominent position. Moreover, the mobilization of magnesium in spring litter solutions may also be the result of the acidification of the solutions by organic acids, whose relative amount in the salt composition of the solutions increases considerably during this period.

In addition to alkali earth bases, litter solutions contain alkali, which is evidenced by the high concentration of chlorides, which are usually associated with them. However, we could not find any alkali in the solutions by calculations, because of their high content of organic acid salts.

The concentration of anions in litter solutions also depends to a certain degree on the methods of separation. This relationship is especially pronounced in chlorides, the contents of which are highest when the displacement and squeezing methods are used. It is considerably lower in lysimetric waters because of their dilution. The active role of the chloride ion in biological processes is evidenced by its accumulation in autumn solutions.

The sulfate ion occupies one of the first places by its absolute content and relative participation in the salt composition of litter solutions. The variations in its content, depending on the method of solution separation, are very clear, but not understood as yet. The higher concentration of the SO_4^{--} in autumn solutions, obtained by the displacement and squeezing methods, as compared to that in lysimetric waters, the formation of which is accompanied by their dilution, is in conformity with the established pattern. But if only this factor were operative, then the $SO_4^{--}:Cl^-$ ratio should have decreased in the lysimetric waters, since the Cl^- is more mobile. However, this ratio does not decrease. As we can see from Table 1, it increases in autumn, and especially in spring. Consequently, the SO_4^{--} discharges into lysimetric waters more rapidly than the Cl^-; their mobility under these conditions is apparently determined by different factors and cannot be compared.

The bicarbonate ion, which is derived from carbon dioxide, reflects to a certain degree in its concentration and relative participation in the salt composition of the solutions, the intensity of biological processes and carbonate equilibrium conditions. In the loose, moderately moist litter, the partial pressure of CO_2 apparently differs little from atmospheric pressure under given meteorological conditions. The carbon dioxide content in lysimetric waters varies from 0.6-0.8 meq/liter, while in the solutions obtained under laboratory conditions it varies around 0.2-0.3 meq/liter. Therefore, alkalinity does not differ much there, it changes primarily with the seasonal characteristics of the hydrothermal regime. It increases in autumn because of the supply of ash elements with fresh litter, and decreases after they become leached during the winter and spring and stronger organic acids accumulate in the solution. Organic substances, in particular acids, predominate quantitatively and are the most characteristic components of the solutions. Even with the incomplete, indirect determination of their participation in the salt composition of solutions obtained by the displacement and squeezing methods, their content in autumn was 2.5%-eq and 8.7%-eq, and in spring 23.5%-eq and 19.3%-eq. The seasonal variations in the content of organic acids are less pronounced in lysimetric waters; there they vary from 12.7%-eq to 14.8%-eq, respectively.

The total index of changes taking place in the composition of the solutions is the pH, which characterizes the state of equilibrium between the bases and acids. The pH varies from 5.9-6.0 in autumn solutions, rich in bicarbonates. After winter-spring leaching and the relative increase of organic acids in the composition of the solutions, active acidity increases; the pH decreases to 4.9-5.3 in solid-phase solutions and to 5.9 in lysimetric waters.

Thus, litter solutions obtained by three different methods have both common and different features. All are characterized by high total concentration, by similar acid-base equilibrium indices, and a low content of mineral compounds. At the same time they differ essentially from each other. Solutions obtained by the displacement and squeezing methods have a much higher total concentration and a wider concentration to total ion ratio, as a result of the direct contact with the solid phase of the litter. The ion concentration of these solutions varies sharply with seasons. It reaches a maximum in autumn, because of the accumulation of salts in the solid phase of the litter, exceeding 1.5-2 times that in lysimetric waters. In spring, however, the ion concentration in solutions, obtained by the displacement and squeezing methods, is the same, or lower than in lysimetric waters, because of the dissimilation and migration of mineral elements into soil water.

Solutions from the A_1 humus horizon are characterized by a sharp (2-3 times and more) decrease in total and ion concentration as compared to those in the litter, independent of the extraction method. As evidenced by the dry residue + 1/2 HCO_3^-/Σ ions ratio, this decrease takes place primarily at the expense of organic compounds, since the amount of dry residue decreases more rapidly than the sum of ions.

The concentration of alkali earth bases and, apparently, that of organic acids decreases in all autumn and spring solutions with the transition into the humus horizons. The content of organic acids cannot be detected by calculation. On the contrary, there is a certain excess of anions in most of the cases here, on the basis of which we calculated alkali.

In spite of the sharp decrease in the concentration of Ca^{++} and Mg^{++} in solutions from the humus horizon, its seasonal variation is very pronounced. Here, as in the litter, the autumn samples contain considerably more calcium than the spring samples. The concentration of magnesium, however, remains almost constant, as a result of which the $Ca^{++}:Mg^{++}$ narrows noticeably in spring.

The absence of lysimetric waters from the A_1 horizon in autumn limits the possibility of comparing the composition of the solutions in relation to the methods of extraction. Such a comparison is possible only for spring samples. It reveals a higher concentration of free CO_2, of the HCO_3^-, and of alkali earth bases in lysimetric waters, and a corresponding increase in the pH as compared to solutions obtained under laboratory conditions, the acid-base equilibrium of which is determined by other components.

Solutions from the podzolic A_2 horizon. A common and most characteristic feature of solutions from the podzolic horizon, which is independent of the extraction method, is the low total and ion concentrations. Their seasonal fluctuations are hardly noticeable. The dry residue + 1/2 HCO_3^-/Σ ions ratio is even more narrow than in solutions from the A_0 and A_1 horizons, indicating a further decrease in the participation of organic compounds in the composition of the solutions. The difference between the ion composition of lysimetric waters and of the solutions, obtained by the displacement and squeezing methods, increases. Sulfates and bicarbonates predominate in the first, and sulfates and chlorides, in the latter.

Solutions from the eluvial-illuvial A_2B horizon were obtained by two methods only, which makes their comparison and conclusions difficult. Their ion concentration is insignificant, even though it shows a tendency to increase in lysimetric waters in autumn and spring.

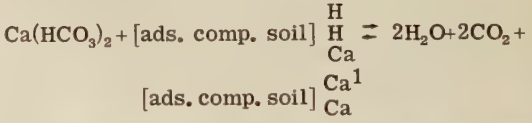
Solutions from the illuvial B horizon. The difference in concentration and the salt composition between the solutions is most pronounced here. The difference is primarily in the changes in the concentration of bicarbonate salts. It is insignificantly small in solutions displaced by alcohol, because of the loss of free CO_2, and the total ions is correspondingly small. However, the total concentration of the solution remains relatively high, exceeding the sum of ions 3.5 times. The reaction of the solution is weakly acid. In lysimetric waters, on the contrary, the amount of bicarbonates and the total ions increase sharply, because of their higher saturation with CO_2. The dry residue + 1/2 HCO_3^-/Σ ions ratio decreases to 1. The reaction becomes neutral.

Thus, solutions of different composition are obtained from the same soil at the same time (or almost nearly the same time) by 3 methods; they differ not only depending on the extraction method used, but also on the properties of the horizons in which they are contained, seasonal moisture conditions, litter supply, and other factors.

A comparative study of the composition of these solutions permits us the following conclusions:

1. The methods of displacing the solutions with alcohol and squeezing do not differ essentially from each other. In both cases solutions are extracted which form under the effect of forces and processes taking place at the surface of soil particicles. Their concentration is highest in the litter and partly in the humus horizon, primarily because of the presence of organic compounds. Anions of organic acids predominate, or at least occupy an important place in their salt composition. The ion concentration of these solutions is closely related to the amount and mineralization of litter. The ion concentration of solutions obtained by the displacement method from the lower part of the soil profile is insignificantly small and apparently changes little with seasons.

2. A very important feature of solutions extracted with alcohol and under pressure is their low content of free CO_2 and its derivatives such as calcium and magnesium bicarbonates, as compared to lysimetric waters. This feature of the solutions being compared is very pronounced and can be attributed only to the change in the carbon dioxide equilibrium in the solid soil phase — soil solution — soil air — atmosphere system during natural soil drying and, especially during sampling and the preparation of the samples for extraction. The free CO_2 contained in the soil air evaporates when it reaches equilibrium with its partial pressure in the atmosphere, while the bicarbonates are destroyed by the adsorption complex of the soil which is not saturated with cations and acts as a complicated polyvalent anion according to the formula:



$$Ca(HCO_3)_2 + [\text{ads. comp. soil}]\begin{matrix}H\\H\\Ca\end{matrix} \rightleftarrows 2H_2O + 2CO_2 + [\text{ads. comp. soil}]\begin{matrix}Ca^{1}\\Ca\end{matrix}$$

Because of the disturbance of the carbon dioxide equilibrium the reaction of the solution shifted. The pH values recorded thereby, which are determined by the presence of weakly dissociated acid compounds, correspond to the newly established equilibrium between the solution and the CO_2 pressure of the atmosphere.

3. Lysimetric waters, which form primarily in large cavities and pores and are less strongly bound with the solid phase of the soil, are characterized by a lower total concentration and a relatively large content of mineral compounds. Penetrating into lysimeters from undisturbed horizons with a high partial CO_2 pressure, they remain saturated with carbon

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[1] Note: We can avoid disturbing the carbonate equilibrium when squeezing out a soil solution if we take certain precautions. The main precautions are: a) taking soil samples in one piece and keeping them in jars with ground stoppers or cellophane; b) squeezing the solutions from soil at its natural moisture content; and c) titrating the solutions immediately after they are extracted.

The high amount of carbon dioxide in lysimetric waters can be caused by their prolonged stay in the lysimeters and the development of biological processes in the waters. -- Editor.

dioxide and are characterized by a higher content of its derivatives — calcium and magnesium bicarbonates, especially in the illuvial horizon. The disturbance of the carbonate equilibrium, which takes place during the movement of lysimetric waters into the receivers and during their pumping to the surface, manifests itself quite differently than in solutions obtained by the displacement and squeezing methods. Lysimetric waters lose carbon dixode when they are isolated from the adsorption complex of the soil which is not saturated with cations. Therefore, the bicarbonates contained in them are not subject to the decomposition effect of the adsorption complex of the soil. When they lose carbon dioxide and change reaction toward alkalinity they can only become normal carbonates:

$$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2,$$

which partially occurs in the waters from the lower horizons, the reaction of which reaches a pH from 6.9-7.0. The reaction of lysimetric waters in the upper part of the soil profile remains slightly acid, as in the other solutions, because of the presence of organic acids in this part of the profile and its insignificant alkalinity.

4. Since the solutions obtained by the replacement and squeezing methods and lysimetric waters reflect various states of the liquid phase of the soil, their composition characterizes the individual links of a very complicated process of the transformation and movement of substances participating in soil formation. Their combined study will make it possible to determine the nature and characteristics of the latter more accurately.

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CLAY DEPOSITS IN FLOOD PLAINS OF THE VOLGA AND MEDVEDITSA RIVERS AND THEIR EFFECT ON SOIL FERTILITY

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Clay is used in agricultural practice in addition to local fertilizers, such as manure, peat, etc. Lake clay (sapropel) has long been used in the USSR to fertilize soils of the non-chernozem zone. The positive effect of clay on the yield of various crops and on the soil fertility in this zone has been described in the works of Polyanskiy (10, 11), Smirnov (14), Vimba and Indriksons (2), and others.

Irrigational deposits in the form of river and irrigation-ditch clay are widely used in the cotton growing areas of Central Asia. In spite of the relatively low percentage of organic substances in these deposits, they have quite a positive effect on the fertility of irrigated sierozems (3, 4, 5, 6, 7, 12, 13). River clay deposits are also used for the improvement of flood-plain soils.

Clay is not used for increasing the fertility of soils in the dry southeast, even though it is well known that flood-plain soils (which are supplied with clay deposits by flood waters) and the lake soils of this region have a high fertility. The foregoing permits us to assume that the use of clay for increasing soil fertility may also be of value in the dry zone of the southeast.

In this zone the major supply of clay is concentrated in the water bodies of river flood plains, and therefore the clay could be used here primarily to improve the coarse-textured flood-plain soils. In the Volga-Akhtuba flood plain alone there is a vast number of lakes, in which the total volume of clay, as reduced to the solid phase, is 15-20 million m^3, according to approximate calculations (15). At the same time, according to the data of Plyusnin (9), 106.5 thousand hectares of the 710 thousand hectares of this flood plain are occupied by cumulative sands and sandy loam soils and 99.4 thousand hectares by cumulative, coarse clay loam and sandy loam sod soils. All these soils (especially the first group) need enriching not only with nutrients but also with organic substances, and also require improvement of their structure and physicochemical properties. We cannot radically change the properties of these soils by adding mineral fertilizers alone. In order to improve their structure, and increase their adsorption capacity and humus content these soils must be enriched with clay particles (especially with organic colloids). Moreover, when clay is added to coarse textured soils it increases their cohesiveness and improves their structure, thus promoting the conservation of these soils from all types of erosion. If the clay contains enough nutrients it can also improve the nutrition regime of the soil, whereby the nutrients will be retained better by the soil than when mineral fertilizers are used. Thus, land with a low fertility, which is now being used primarily for meadows and pastures, which are often non-productive, could be made fertile and suitable not only for high-productive forage land, but also for valuable vegetable and commercial crops.

The fertility of soils can be improved with clay deposit also when levelling flood plains. Levelling is necessary because of the uneven relief of the flood plains. When levelling an area, the lower layers which have a low humus content and a low fertility (often consisting of almost pure sand), are brought to the surface. Plants sown in such soil lack normal growth conditions. The addition of clay to the levelled areas could increase their fertility greatly. Clay can also be used during levelling as a fill in relief depressions. This is the way it was used in an experiment made by the Stalingrad experimental-melioration station in a diked area called "Zapornaya polyana" in the northern part of the Volga-Akhtuba flood plain. Sheppel' (15, 8), and Arshinova (1, 8), who conducted this experiment, noted the positive effect of clay deposit on the fertility of gray alluvial soil. The addition of clay improved the physical properties of this soil, and enriched it with humus and nutrients, as a result of which much higher crop yields were obtained in clay deposited plots than in the control plots. Arshitnova relates the improvement of the physical properties of the soil to the formation of a good granular structure. According to her data, the amount of water-stable aggregates in this soil amounts to more than 80%, consisting primarily of aggregates from 1-3 mm in diameter. The same author reports that no such solid crusts formed in the furrows of the clay deposited soil as did in the control, and that pre-sowing soil tillage can be eliminated in areas where clay was added in autumn, because the clay changes into a friable, structural mass during winter.

The data given in the reports of the Stalingrad

Table 1

Crop yield on plots with added clay and on control plots, cntr/ha

Crop	Year of adding clay	Years								
		1955	1956		1957		1958		1959	
		Plots with added clay		Control[a]	Plots with added clay	Control[a]	Plots with added clay	Control[a]	Plots with added clay	Control[a]
Tomatoes	1954	856	720	475	—	—	—	—	—	—
	1955	—	940		808	642—652	—	—	—	—
	1956	—	—	—	570	478—535	—	—	—	—
Corn	1954	101	125	41—85	—	—	—	—	—	—
	1955	—	134		104	67—72	—	—	—	—
	1956	—	—	—	99	—	—	—	—	—
Potatoes	1954	133	149	—	—	—	—	—	—	—
	1955	—	176	91—145	—	—	—	—	—	—
Cucumbers	1955	—	—	—	—	—	479	—	—	—
	1956	—	—	—	—	—	514	306—341	—	—
Barley (biological yield)	1954	—	—	—	—	—	—	—	21	14
	1955	—	—	—	—	—	—	—	26	
	1956	—	—	—	—	—	—	—	28	

[a] The two figures in the control indicate: the lower — yield on elevated relief, and the higher — yield in the depressed relief elements of the levelled plots.

experimental-melioration station for 1956-1959 (8) are presented in Table 1.

The foregoing experiment is unique under the conditions of the southeast: data on the effect of clay deposit on the fertility of soils in this zone and on the properties of the clay proper are very limited. Huge clay masses with their nutrients still lie untouched in flood plains, finding no application in the agriculture of arid zones. Taking the foregoing into account, we began the study of the possibility of using the clay deposit of flood plain lakes to increase the fertility of alluvial soils under the conditions of the arid southeast.

In 1958 and 1959 we analyzed soil samples taken from the earlier-mentioned plot at the Stalingrad experimental-melioration station, where clay deposit was used for levelling the soil surface.[1] The Lake Zapornoye clay was added on plots in the autumn of 1954, 1955, and 1956. The clay deposited plots were 165 m long and from 15-20 m wide (depending on the slope of the levelled depressions. Soil samples were taken from the control plot and from clay deposit plots with different years when clay was added. Since the entire area was used for a number of years for growing agricultural crops (primarily vegetables) and had been tilled many times, the clay deposit layer became mixed with the underlying soil horizons and the boundary between them had been obliterated.

The relief of the control plot, as that of the flood plain beyond the limits of the levelled area is uneven, with low ridges and depressions between them. Therefore we took soil samples in this plot separately from the ridges and the depressions. The ridges are occupied by coarse-textured soils with a shallow humus horizon and a low humus content. The soils in the depressions are of finer textures, thicker, and contain more humus.

The results of the chemical analyses of the soil samples are presented in Table 2. The data in Table 2 show that the soil with the deposited clay layer is considerably richer in humus and nutrients than the soils of the depressions and, especially, ridges of the control plot. The humus and nitrogen content of the plowed layer of deposited clay soil is 2.5-2.7 times higher than in the ridges and 1.2-1.5 times higher than in the depressions of the control plot. This difference is also large in the subplow layer, especially as compared to the poorer soils of relief elevations. Depositing clay to the soil lead to an increase not only of the total nitrogen content, but also in the content of hydrolyzable nitrogen. The amount of the latter is 1.5-2 times higher in the soil of the

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[1] V.A. Yurina took part in the analyses.

Table 2

Content of humus and nutrients in the soil of the control plot and in clay deposited plots[a]

Place of sampling	Depth, cm	In % of absolutely dry soil					In mg/100 g of absolutely dry soil					
		Total					Available					
		Humus		N		P_2O_5	N		P_2O_5		K_2O	
		1958	1959	1958	1959	1958	1958	1959	1958	1959	1958	1959
Control, ridge	0—20	1,03	1,14	0,096	0,095	0,100	6,4	7,8	3,0	3,0	15,7	12,7
Same	20—40	1,00	0,87	0,072	0,072	0,089	4,9	4,8	3,4	2,1	9,3	12,0
Control, depres.	0—20	2,18	2,01	0,176	0,214	0,156	8,8	9,6	4,0	4,3	19,2	24,9
Same	20—40	2,00	1,77	0,171	0,178	0,137	6,8	5,1	2,7	2,3	15,2	18,6
Clay deposited '56	0—20	2,75	2,80	0,268	0,273	0,190	15,7	15,3	4,4	3,3	20,4	21,0
Same	20—40	—	1,90	—	0,173	—	—	8,7	--	3,0	—	18,5
" " '55	0—20	2,55	2,56	0,224	0,243	0,177	9,5	9,6	5,1	3,0	17,6	24,9
	20—40	—	2,11	—	0,208	—	—	6,7	—	3,8	—	15,5
" " '54	0—20	2,79	2,77	0,240	0,232	0,187	13,1	10,2	6,1	8,8	20,4	19,6
	20—40	—	2,06	—	0,198	—	—	9,6	—	4,3	—	18,7

[a] The analysis were made: according to the Tyurin method for humus; according to the Kjeldahl method for total nitrogen; according to the Tyurin and Kononova method for hydrolyzable nitrogen; according to the Sokolov method for total P_2O_5; according to the Machigin method for available P_2O_5; and according to the Brovkina method for available K_2O.

Note: Comma represents decimal point.

clay deposited plot than in the soil of the ridges; the difference between the clay deposited soil and the soil in the depressions is somewhat smaller, but still noticeable.

Clay deposit also had a positive effect on the total content of phosphoric acid. The amount of P_2O_5 was smaller in the control plot than in the clay deposited soil. The difference in the P_2O_5 content was especially great between the clay deposited soil and the ridges of the control. As far as available P_2O_5 is concerned, there was no noticeable difference in its content in the control and in the experimental plots.

The content of available K_2O is rather high in the depressions, differing little from its content in the clay deposited soil, but the latter is richer in available forms of K_2O than the soil of the ridges. Microbiological analyses made by us in 1958 showed that the number of bacteria, growing on meat-peptone-agar, and nitrifying bacteria is 3-5 times higher in the clay-deposited plots than in the control plot. As far as the number of bacteria is concerned, the clay deposited soils are closer to clay than to the soil in the control plot. This indicates that microorganisms, supplied to the soil with the clay deposit, not only acclimatize well here, but develop successfully, finding favorable conditions. It is interesting to note that the better structure of the plowed layer of clay deposited soil is noticeable to the eye, even 4-5 years after the addition of clay.

We can see from the foregoing data that the clay deposit in soil had a positive effect on its fertility. This effect is stable and is effective for a long time. It manifests itself clearly on the fourth and fifth year after depositing clay and will probably last in the future. The positive properties of deposit clay soil are especially noticeable when it is compared with the coarse-textured soils of the ridges.

We studied certain chemical and microbiological properties of the clay from Lake Zapornoye, which was used in the foregoing experiment. The lake is located in a diked area on the left bank of the Volga River 7 km from it, in an area transitional from along the river to the central flood plain. Its inundation by flood water is regulated. In addition to the clay deposit from Lake Zapornoye, we studied clay deposits from several other water bodies in the Volga and Medveditsa River flood plains. The following samples were taken in the Volga River flood plain.

1. Clay deposit from Lake Ponomarevo, located on the left bank along the river flood plain. The lake is inundated during floods, while during the low-water period it is not connected with the Volga River.

2. Clay deposit from the Shumey back waters.

3. Clay deposit remaining on the soil surface

after the Volga River flood subsides. Taken along the river flood plain from "Zelenyy" island.

Clay deposit was taken from 2 lakes in the Medveditsa River flood plain: Lakes Tan'kino and Sazan'ye, located in the upper part of the left-bank along the river flood plain (belonging to the "Krasnoarmeyets" sovkhoz, Atkar rayon, Saratov Oblast'). Lake Tan'kino is not connected with the Medveditsa River, but is inundated almost every year by flood waters. Lake Sazan'ye is connected with the Medveditsa River by a narrow slough.

The study of the foregoing clay deposits in the laboratory showed that the clay from Lake Zapornoye is finely dispersed clay, the rest of the clay deposits are coarsely dispersed (Table 3).

The primary role in the formation of these clay deposits is played by the geological factor (supply of solid particles from land areas), other factors of clay deposit formation playing a subordinate role. The clay deposits from various water bodies differ. The differences between them depend on many conditions: climate, vegetation and soils of the river basin, location of the water body in the area of the flood plain, vegetation and water regime of the water body, and others.

The results of chemical analyses are presented in Tables 4 and 5. We can see from Table 4 that the amount of humus in the clay deposits investigated varies greatly, from 1.34%-7.65%. Clay deposits from lakes in the Medveditsa River flood plain are the richest in humus; this is associated with the nature of the deposits, derived from an area occupied by very humic soils (thick and ordinary chernozems), as well as with the greater development of vegetation in the lakes proper. The lakes from the Volga flood plain, from which the clay deposits were taken, are located in an area with less humic soils (southern chernozems, chestnut soils) and have a comparatively poor vegetation.

The location of a water body in the area of the flood plain is also of great importance. Flood water brings fine particles with a higher content of organic substances into Lake Zapornoye, which is located at the boundary of the central flood plain, than into lakes located

Table 3

Particle-size analysis of clay deposits, %

Sampling area		Particle diameter, mm						
		1—0,25	0,25—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001	Total <0,01
Clay layer	Volga River flood plain	0,06	16,19	24,72	6,34	10,63	42,06	59,03
Lake Zapornoye[a]		0,70	6,42	13,60	8,93	14,37	55,98	79,28
Lake Sazan'ye	Medveditsa River flood plain	0,85	19,90	21,38	6,57	10,90	41,46	58,93
Lake Tan'kino		0,26	35,27	24,50	3,71	5,69	30,57	39,97

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[a] Date for the Stalingrad experimental-melioration station.

Note: Comma represents decimal point.

Table 4

Content of humus and nutrients in clay deposits

Sampling area		In % of absolutely dry silt			C : N	In mg/100 g of absolutely dry silt		
		Total				Available		
		Humus	N	P_2O_5		N	P_2O_5	K_2O
Clay deposit layer	Volga River flood plain	2,16	0,162	0,226	7,8	10,7	12,1	35,4
Lake Ponomarevo		2,40	0,180	0,124	7,7	14,3	4,2	27,8
Lake Zapornoye		4,26	0,420	0,167	5,9	16,4	7,0	36,2
Shumey black water		1,34	0,126	0,176	6,1	10,7	14,9	16,8
Lake Sazan'ye	Medveditsa River flood plain	7,65	0,591	0,655	7,5	19,4	21,4	80,8
Lake Tan'kino		5,71	0,415	0,261	7,9	18,2	10,7	34,2

Note: Comma represents decimal point.

Table 5

Group composition of humus in clay deposits (analyzed by the I. V. Tyurin method)

Sampling area		Carbon										C of fulvic acids	C of mobile humic acids	
		Initial sample	In substances extracted with benzene alcohol	Decalcinate	Fractions[a]									
					Humic acids			Fulvic acids			Residue			
					I	II	Total	I	II	Total		C of fulvic acids	% of total C in soil	% of C of humic acids
In % of clay deposit weight														
Clay deposit layer	Volga River flood plain	1,25	0,09	0,06	0,21	0,04	0,25	0,29	0,04	0,33	0,59	0,76	0,03	
Lake Ponomarevo		1,38	0,15	—	0,21	0,07	0,28	0,31	0,06	0,37	0,58	0,76	0,09	
Lake Zapornoye		2,34	0,23	0,39	0,30	0,09	0,39	0,47	0,10	0,57	0,76	0,68	0,07	
Lake Sazan'ye	Medveditsa River flood plain	4,43	0,35	0,04	1,25	0,31	1,56	0,90	0,07	0,97	1,51	1,60	0,53	
Lake Tan'kino		3,14	0,13	0,07	1,30	0,13	1,43	0,57	0,08	0,65	0,86	2,20	0,51	
In % of total organic carbon														
Clay deposit layer	Volga River flood plain	100	7,20	4,80	16,80	3,20	20,00	23,20	3,20	26,40	41,60	—	2,40	12,0
Lake Ponomarevo		100	10,80	—	15,20	5,10	20,30	22,50	4,30	26,80	42,10	—	6,52	32,1
Lake Zapornoye		100	9,92	16,66	12,82	3,84	16,66	20,08	4,27	24,35	32,49	—	3,00	17,9
Lake Sazan'ye	Medveditsa River flood plain	100	7,90	0,90	28,22	7,00	35,22	20,31	1,58	21,89	34,09	—	11,96	34,0
Lake Tan'kino		100	4,14	2,27	41,40	4,14	45,54	18,12	2,55	20,67	27,38	—	16,24	35,6

[a] Fraction I – humic substances extracted from the clay deposit with 0.1 N NaOH after decalcification; fraction II – same, after alternate treatment of the clay deposit with acid and alkali.

Note: Comma represents decimal point.

along the river of the flood plain, such as for instance Lake Ponomarev, where the deposits brought are coarser-texture and contain more mineral particles.

The C:N ratio is narrower in all clay deposits, varying from 5.9-7.9. This points to an unusual humus composition, which contains substances with a high relative nitrogen content.

Not only the amount of humus, but also its composition in the clay deposit must have an essential effect on soil fertility. Data in Table 5 show noticeable differences in the group composition of humus in the clay deposits. The clay deposits from lakes in the Medveditsa flood plain (Lakes Sazan'ye and Tan'kino), which have a high humus content, are distinguished by a high percentage of substances forming the group of humic acids (35%-45% of total soil carbon). The majority of these substances forms polymer complexes, saturated with Ca, since the amount of "mobile" acids, extracted with 0.1 N alkali without previous soil decalcification, is only 11%-16% from the total C in the soil. There are much less humic acids supposedly bound with stable forms of R_2O_3 (group II). There are much less substances of the fulvic acid group in these clay deposits than there are humic acids. The ratio between the C of humic acids and the C of fulvic acids is 1.6 (deposit from Lake Sazan'ye) and 2.2 (deposit from Lake Tan'kino). Substances forming the non-hydrolyzable residue comprise about one third of the humus.

The humus in clay deposits taken from the lakes of the Volga flood plain differs considerably in its composition from the humus in the clay deposits of the lakes in the Medveditsa flood plain. The content of humic acids is considerably less in the deposits from Lakes Ponomarevo and Zapornoye, both in absolute value as in relation to the fulvic acid content. The ratio between the C of humic acids and the C of fulvic acids in the humus of these clay deposits is from 0.68-0.76, i.e., fulvic acids clearly predominate. Humus in the deposit from Lake Zapornoye is characterized by a high content of substances extracted during decalcification.

The amount and composition of humus in the Volga clay deposit, taken in the area along the river flood plain, proved to be very close to that of the clay deposit from Lake Ponomarevo, located in the same section of the flood plain. This indicates that the major source of Lake Ponomarevo deposit and of similar lakes is the supply of suspended particles during floods.

The clay deposits from various water bodies differ from each other by their total amount and content of nutrients available to plants (Table 4). The total nitrogen content in the samples investigated varies from 0.126% to 0.591% and corresponds to the humus content. A considerable part of the nitrogen is in easily-hydrolyzable compounds and, consequently, can rapidly change into forms available to plants.

The clay deposits differ greatly from each other in the content of total and available phosphoric acid. The amount of total P_2O_5 varies from 0.124% to 0.655%, while that of available P_2O_5 varies from 4.2-21.4 mg/100 g of absolutely dry clay deposit, whereby there is no direct correlation between the humus content and total P_2O_5 and also between the total and available P_2O_5.

A high content of K_2O available to plants was found in all the clay deposits investigated (except the clay deposit from the Shumey back water), varying from 27.8-80.8 mg/100 g of absolutely dry weight.

The foregoing data indicate that the addition of clay deposit to the soil must have a great effect on its fertility. Humic substances and other colloids contained in it are an important factor in structure formation and must improve the physical properties not only of coarse-textured soils, but probably also of fine-textured soils; clay deposit transforms into a structural, granular mass under the influence of low temperature and drying in winter, capable of improving the physical properties of fine-textured soils also. The high content of nitrogen and its easily hydrolyzable compounds, and the large amount of Azotobacter in many of the clay deposits would not only promote the general enrichment of the soil with nitrogen, but would also increase the content of its compounds available to plants. The large amount of available K_2O in the clay deposits, as well as the richness of certain clay deposits in P_2O_5, including its available forms, must improve the phosphorous and potassium nutrition of plants, which is especially important in sandy soils.

The large number of microorganisms in clay deposit would intensify fermentation, which, together with the enrichment of the soil with humus and nutrients, would improve its entire nutritional regime. The degree of effectiveness of various clay deposits on soil fertility will differ, depending on the properties of the clay deposit used.

The clay deposits of many flood-plain water bodies in the Southeast, which have a huge supply of organic substances and plant nutrients, which are rich in colloids and amply populated with microorganisms, may find practical application for improving the fertility of the soils of this zone. It must be noted that there may be certain undesirable phenomena when clay deposit is added to the soil, such as for instance the negative effect on plants of hydrogen sulfide, contained in clay deposit. Observations show that this is easily eliminated by adding clay deposit in autumn, as well as by regulating the thickness of the deposit layer. In order to utilize rationally the clay deposits, they and the conditions of their application must be studied thoroughly.

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COLLOID-CHEMICAL PROPERTIES OF HUMUS COMPOSTS

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Humus forms as a result of the decomposition of plant and animal residues by microorganisms under aerobic or anaerobic conditions. Because of local climatic characteristics the organic matter decomposes very rapidly. Long-term field crop rotation, which is successfully used, exhausts the soil. Therefore, in order to utilize better the land, organic matter must be systematically added to it.

Experimental

The method of preparing compost was borrowed by us from Riad (4). We used corn stalks as the initial material. To prepare the artificial manure, the following activators were added to each metric ton of stalks: 39.5 kg of Chile saltpeter (15.5% N); 5.0 kg of calcium superphosphate (15.5% P_2O_5); and 5.0 kg of slaked lime to create a neutral or slightly alkaline medium for the activation of microbiological processes. To prepare H-humus from the decomposed material the latter was treated with 0.05 N HCl. The treatment was repeated until the material was free of exchangeable cations. Then it was washed with water several times until there was no reaction to chloride. Table 1 gives the results of the analysis of the initial compost material and the H-humus obtained.

Colloid-chemical Properties

Total adsorption of alkali hydroxides and alkali earths. One gram of air-dry H-humus was placed in a 100 ml beaker, a little water was added to it, and then increasing amounts of Li, Na, K, NH_4, Ca, and Ba hydroxides, and the whole was brought to volume of 10 cm^3 with twice distilled water. When equilibrium was reached, the more or less colored settled solution was titrated to a pH of 5.2 and 8.2 titrometrically and electrometrically. The results are presented in Tables 2 and 3 and in Figures 1 and 2.

It is obvious that alkali earth hydroxides are more strongly adsorbed than alkali. This is attributable first of all to the higher solubility of alkali humates and the higher valence of alkali earth cations. The adsorption curves of alkali hydroxides are convex and show a tendency to reach their final values at initial concentration, equal to 30 meq of hydroxide per 10 g of H-humates, the curves for alkali earths reach their final values at higher hydroxide concentrations. The degree of adsorption of alkali as well as alkali earth hydroxides increases as hydroxide concentration increases.

The adsorption curves usually obey the

Table 1

Chemical composition of the material, % of dry substance

Components	Initial compost substance	H-humus
Ignition loss	43,58	60,37
Ash	56,42	39,63
Fraction soluble in ether	0,33	0,67
Organic: carbon	25,25	33,56
substance (x 1.724)	43,53	57,86
nitrogen	1,45	3,10
Total proteins (x 6.25)	9,06	19,38
C:N (molecular ratio)	14,96	9,28

Note: Comma represents decimal point.

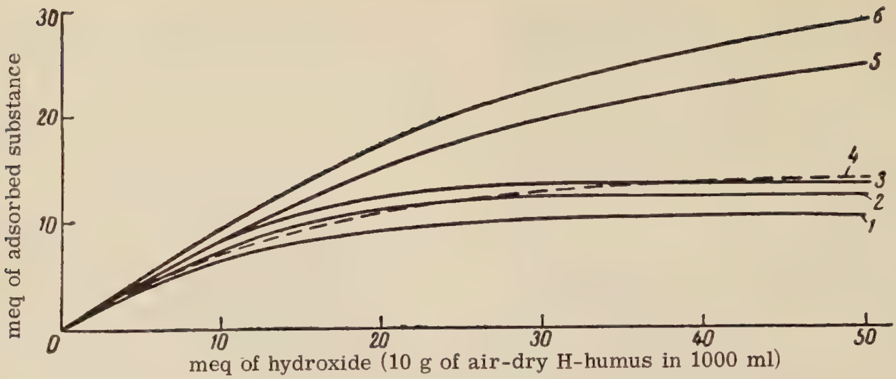

Fig. 1. - Adsorption of alkali and alkali earth hydroxides during titrometric analysis using the mixed indicator of Kolthoff.

1 - NH_4OH; 2 - LiOH; 3 - NaOH; 4 - KOH; 5 - $Ba(OH)_2$; 6 - $Ca(OH)_2$

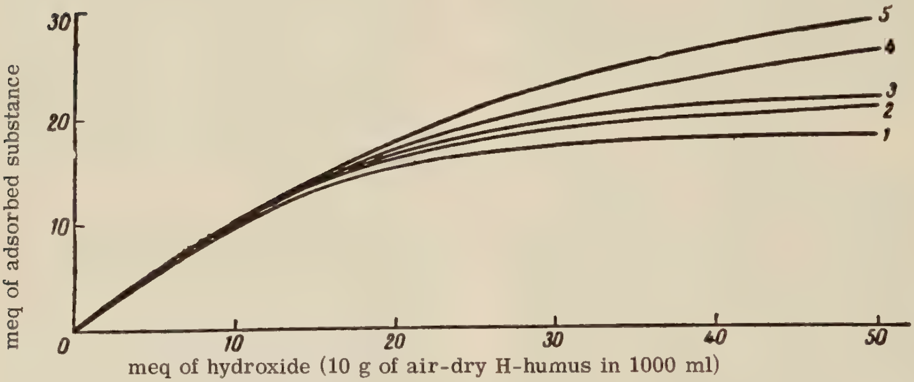

Fig. 2. - Adsorption of alkali and alkali earth hydroxides during electrometric titration to a pH of 8.2.

1 - NaOH; 2 - LiOH; 3 - KOH; 4 - $Ba(OH)_2$; 5 - $Ca(OH)_2$

Table 2

Total adsorption of alkali and alkali earth hydroxides in meq/10.00 g of air-dry H-humus. The Kolthoff indicator with a pH of 5.2 was used.

Hydroxides	Initial concentration, meq							
	5	10	15	20	30	50	80	100
LiOH	4,57	7,36	10,05	12,06	12,66	12,36	12,67	12,94
NaOH	4,45	8,17	11,57	12,85	13,77	13,88	—	—
KOH	4,25	7,24	9,36	11,07	13,75	14,10	13,70	14,20
NH_4OH	4,40	7,50	7,96	9,59	10,81	10,50	10,46	—
$Ca(OH)_2$	4,77	8,29	—	17,43	26,00	28,67	32,24	35,57
$Ba(OH)_2$	4,57	8,94	—	15,25	22,50	25,00	29,33	29,80

Note: Comma represents decimal point.

AGRONOMY

Table 3

Total adsorption of alkali and alkali earth hydroxides, meq/100 g of air-dry H-humus, determined electrometrically at a pH of 8.2

Hydroxides	Initial concentration, meq							
	5	10	20	30	40	50	80	100
LiOH	5,00	10,00	15,42	19,17	20,26	20,82	21,40	21,93
NaOH	5,00	10,00	15,68	18,12	17,62	19,17	—	—
KOH	5,00	10,00	15,57	19,73	20,65	21,78	22,00	22,09
$Ca(OH)_2$	5,00	10,00	17,27	23,03	27,42	29,49	33,99	35,97
$Ba(OH)_2$	5,00	10,00	16,70	21,25	24,16	26,44	30,92	32,08

Note: Comma represents decimal point.

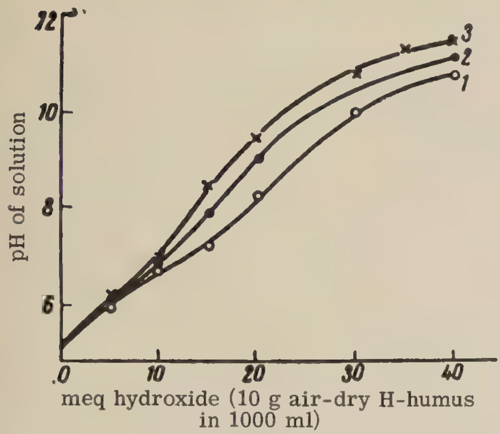

Fig. 3. - Alkali hydroxide titration curves of H-humus (settled solutions).

1 - KOH; 2 - LiOH; 3 - NaOH

Table 4

Exchange capacity of H-humus under treatment with calcium acetate

Extraction	pH of settled solution	meq NaOH used for titrating 10 g of H-humus
1	5,80	7,36
2	6,30	10,40
3	6,65	11,50
4	6,95	12,19
5	7,00	12,73
6	7,30	13,11
7	7,32	13,46
8	7,32	13,82
9	7,38	14,08
Graphical extrapolation	—	Σ 14,50

Note: Comma represents decimal point.

log-log equation or the Freundlich equation, since they have a more or less slight curvature, in the direction of the axis of the abscissa. The order of adsorption is the following:

$$NaOH < LiOH < KOH < Ba(OH)_2 < Ca(OH)_2$$

Exchange capacity of H-humus, as determined with 1 N calcium acetate.

The exchange capacity is determined in the following manner: 10 g of air-dry H-humus are placed in an enclosed 500 ml flask, then 250 ml of 1 N Ca acetate with a pH of 8.2 are added to the same flask, and shaken for 1 hr. The filtrate is completely titrated to a pH of 8.2 with 0.05 N NaOH. The 1 N calcium acetate is added and titration is repeated until all the H-ions are replaced with Ca ions. Table 4 shows the results of this treatment. It is obvious that the exchange capacity coincides with the deflection point, which is found by discontinuous electrotitration of NaOH, the amount of which can be 14 meq/10 g of H-humus.

Table 5

Position of deflection points on electrotitration curves in the system of alkali hydroxides

Hydroxides	pH at the deflection point	Concentration in meq at the deflection point per 10 g of colloids
LiOH	8,5	17,6
NaOH	8,5	14,6
KOH	8,2	20,0
	8,4+0,1	17,4+1,6

Note: Comma represents decimal point

Electrometric Titration of H-humus

The qualitative determination of the exchangeable H-ion is extremely important for the evaluation of the exchange capacity. To study the behavior of H-humus in relation to bases we made the following experiments.

I. Discontinuous electrotitration with alkali hydroxides. As we know, the ions at the surface of humus colloids belong primarily to carboxyl COOH radicals and phenol hydroxyl groups.

Figure 3 shows that the point of deflection coincides with the neutralization of the COOH group, while the neutralization of the phenol OH groups occurs at higher pH values, i.e., below the deflection point.

The results presented in Table 5 show that according to buffer action the three alkali systems may be distributed in the following manner: Na humate < Li humate < K humate (1, 2).

II. Titration curves of H-humus with NaOH and $Ba(OH)_2$. Electrotitration was conducted by the standard method.

If we examine Table 6 and Figure 4 it becomes clear that the alkali titration curve differs greatly from the alkali earth titration curve.

The NaOH curve rises sharply from the initial pH values of the system. Both curves have a single, relatively clearly defined deflection point. The neutralization point was pH 7.6 for NaOH at 1.26 meq per gram and pH 7.4 for $Ba(OH)_2$ at 1.35 meq per gram. This difference is attributable to the fact that alkali humates, like salts of weak acids salt, are easily hydrolyzed and give a weakly alkaline reaction, while alkali earth humates are less soluble and therefore do not give a sufficient

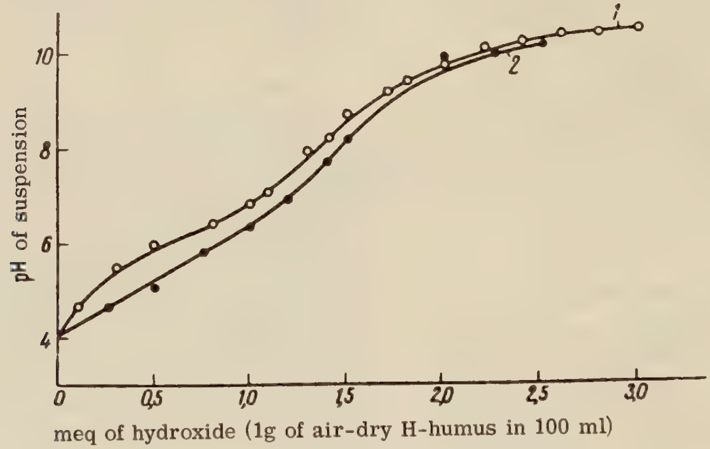

Fig. 4. - Curves of the discontinuous electrotitration of H-humus with NaOH and $Ba(OH)_2$.

1 - NaOH; 2 - $Ba(OH)_2$

Table 6

Discontinuous electrotitration of H-humus with NaOH and $Ba(OH)_2$

NaOH, meq/100 ml	pH	$Ba(OH)_2$, meq/100 ml	pH	NaOH, meq/100 ml	pH	$Ba(OH)_2$, meq/100 ml	pH
0,00	4,10	0,00	4,10	1,50	8,70	2,25	10,00
0,10	4,70	0,25	4,70	1,70	9,20	2,50	10,20
0,30	5,50	0,50	5,10	1,80	9,40	—	—
0,50	6,00	0,75	5,80	2,00	9,75	—	—
0,80	6,40	1,00	6,35	2,20	10,10	—	—
1,00	6,80	1,20	6,90	2,40	10,20	—	—
1,10	7,10	1,40	7,70	2,60	10,40	—	—
1,30	7,95	1,50	8,20	2,80	10,40	—	—
1,40	8,20	2,00	9,00	3,00	20,50	—	—

Note: Comma represents decimal point.

amount of hydroxyl ions during hydrolysis. Moreover, both titration curves do not have definite inflections corresponding to dissociation constants, which could have been expected for polybasic acids.

The slope of the NaOH titration curves is steeper than that of the $Ba(OH)_2$ titration curve, because of the higher activity of the Na ion (2).

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PROBLEM OF DETERMINING THE POTASSIUM CONTENT IN SOILS FROM γ RAYS

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The purpose of the present article is to determine the practical possibilities of using the radioactive radiation of potassium-40 for determining the potassium content in soils from observations directly at the soil surface (without taking samples), as well as at a certain height above it (from an airplane).

1. There are 3 potassium isotopes under natural conditions – potassium-39, potassium-40, and potassium-41, which have a constant ratio in terms of the number of atoms (in percents) of 93.08:0.0119:6.91. Of these only potassium-40 is radioactive, having a half-life of 1.31 x 10^9 years. The potassium-40 atoms decay in two ways: by the decay of β particles and the formation of calcium-40, the decay probability being ~88%, the maximum energy of β particles being 1.3 Mev; and by k-capture and the formation of argon, accompanied by γ radiation with a quantum energy of 1.46 Mev. The intensity of these radiations during measurement at the soil surface (or from soil samples) is proportional to the potassium content. However, since soils always contain other radioactive elements (elements of the uranium and thorium families, for instance), the total intensity of β- and γ-radiation at the soil (sample) surface is determined by the total content of β- and γ-radiating soil radioisotopes. Let us note that the number of β particles, emitted from a unit surface of the soil, and owing to elements of the uranium and thorium families, is usually commensurate with the number of β particles owing to the potassium-40 radioisotope (the possible ratios of these numbers vary from 1:1 to 1:10). Moreover, because of nuclear weapons tests, the upper layer of soil and vegetation is contaminated by radioisotopes – fission debris. The level of β radiation (number of β particles from 1 cm²/sec of soil) of these products was several times higher in 1958 than the level of natural β radiation (total radiation from the β radiation of potassium-40 and the radioactive uranium and thorium families) (5).

The study of the natural β field is also complicated by the fact that the content of fission debris varies depending on the geographical location of the observation area (a pronounced latitudinal effect [8]), its landscape, the amount of precipitation, and a great number of other factors. We must consider these circumstances when interpreting the results of observations on the β radiation of soils, made either with the purpose of determining the total natural radioactivity of soils, or one of the β-radiating radioelements (potassium-40, for instance). If we do not do it, we may come to erroneous conclusions. Thus, the systematic increase of the radioactivity of the upper soil layers as reported by Yastrebov (7) from β measurements, as well as the increase of the radioactivity of this soil layer in a meridional direction, are apparently due primarily to fission debris, but not to changes in natural radioactivity, as it is maintained in his paper.

The possibilities of the β-spectrometry of potassium are also limited. In fact, the β-radiation of potassium-40 (as that of other radioisotopes) has a continuous energy spectrum, which makes it very difficult to distinguish β rays caused by potassium-40 from the β rays of other radioelements contained in soils. Moreover, the maximum distance reached by the β rays of potassium-40 in soils is only several millimeters, which, naturally, limits the possibilities of investigation.

The levels of γ radiation (according to the number of particles as well as to other summary parameters – strength of the dosage, intensity) at the soil surface, created by radioactive potassium and other natural radioelements in soils, are commensurate. The share of γ radiation from fission debris at the present global contamination level is not more than several percent, and can be neglected.

Considering the foregoing, we find it more expedient to determine the potassium content in soils from observations of the energy of γ rays. In fact, the distribution of γ quanta by energy at the soil surface (as well as in samples) possesses a certain characteristic consisting in the fact that at the usual potassium concentrations in soils (1.0%-2.0%) the monochromatic line with an energy of 1.46 Mev, owing to potassium-40, is very pronounced. This makes it possible to use the scintillation method in γ-spectrometry to determine γ quanta with an energy of 1.46 Mev. Let us discuss the physical principles of this method.

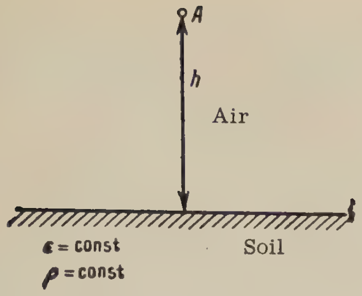

Fig. 1. - Diagram of the distribution of γ-radiation sources and absorption media.

2. Let us assume that the source of γ quanta in the soil (potassium-40 atoms in our case) is distributed evenly at a certain constant concentration ϵ. Let us designate the energy of the emitted quanta with E_0. Let us examine the spherical volume V with a unit cross section, located at point A at a height h from the soil surface (Fig. 1). Let us also assume that soil density is constant and equal to ρ. A certain number of quanta N passes every second through volume V. They can be divided in two groups according to energy — quanta with an energy E_0 (direct or non-scattered rays) and quanta having an energy less than E_0 (arising as a result of the interaction between primary γ radiation and the atoms of the absorbing medium). Let us assume that the number of quanta in each group is N_0 and $N_{scat.}$ so that $N = N_0 + N_{scat.}$. The magnitudes of N_0 and $N_{scat.}$ depend on the concentration ϵ, height h, energy E_0, and the properties of the absorbing medium. It is clear that N_0, N_{scat}, and N are proportional to the concentration of γ-quanta sources in the soil, under otherwise constant conditions. From this it follows that the concentration of sources in the soil is identical according to the values of either N, N_0, or $N_{scat.}$, measured at the point with known properties of the absorbing media (soil, air) and a known height h.

Actually the soil contains several different sources of γ radiation (elements of the uranium and thorium families, radioactive potassium, products of nuclear explosions), which complicates the determination of the content of any radioelements of interest to us. However, γ quanta gives a large amount of information both about radiation sources and absorbing

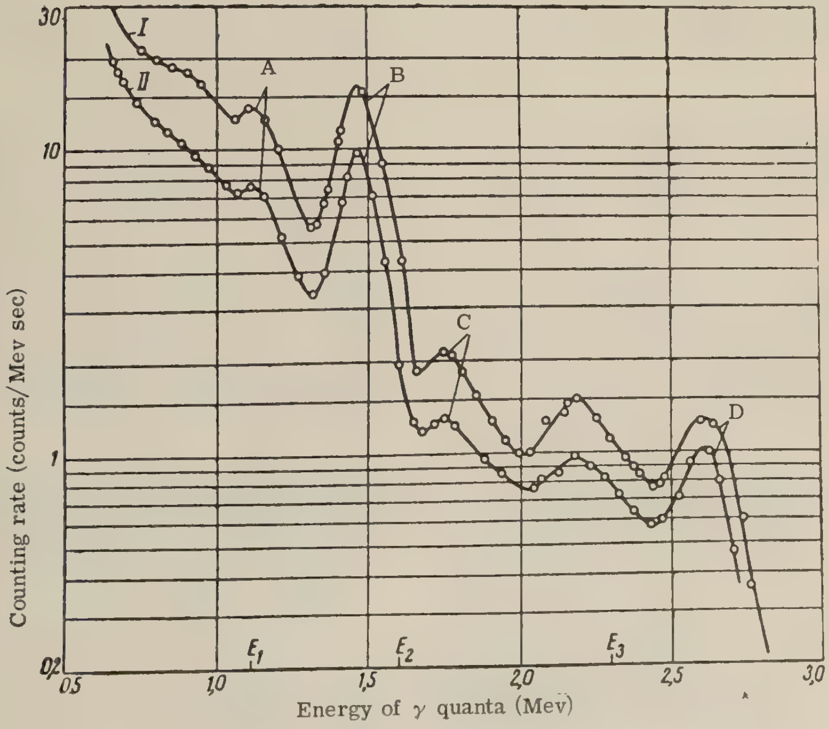

Fig. 2. - Instrumental γ-radiation spectra, measured by a spectrometer with a NaI (Tl) crystal (80 mm in diameter, 60 mm thick), at the surface of two soil groups:
I - light-gray and gray podzolized forest soils (Table 2, Profile 12);
II - slightly and moderately podzolic sod and soils (Table 2, Profile 9).
A - photopeak of radium ($E\gamma$ = 1.1 Mev); B - potassium photopeak ($E\gamma$ = 1.46 Mev); C - radium photopeak ($E\gamma$ = 1.76 Mev); D - thorium photopeak ($E\gamma$ = 2.62 Mev).

media. In fact, the quantum field at the point of observation A, created by the sources, is characterized not only by the numbers of N_0 and $N_{scat.}$, but also by the angular and energy distributions of the quanta.

It is clear that in the concentrate case examined (soil density does not change with depth, radiation sources are evenly distributed in the soil) the number of parameters, characterizing radiation at point A, is fully sufficient to find the concentrations of all the radioactive γ-radiating isotopes contained in the soil. In fact, if we know $N_{0,i}$ and $E_{0,i}$ belonging to an i radioisotope, only, the unknown concentrations are determined similarly from the known values of h and ρ. The possibilities of the γ method are examined in more detail in the work of Fridman (6).

Measurements of γ radiation by means of integrating instruments (Geiger counters, ionization chamber) are associated with a loss of information on the field studied (6). The use of scintillation spectrometers decreases the loss of information considerably. Thus, by using a scintillation spectrometer with a sufficiently good resolving power (each monochromatic line is self-determining), we will obtain 3 m independent $E_{0,i}$ $N_{0,i}$ $N_{scat.\ i}$ values, where m is the number of independent monochromatic lines. Such a volume of information is fully sufficient to determine the sought after concentrations of all the elements (provided ρ=const, ϵ=const). Figure 2 gives an example of the spectrogram, or the so-called instrument spectrum (distribution of counts by amplitudes at the exit of the scintillation spectrometer – a system consisting of a scintillating crystal, a photoelectronic multiplier, and count amplitude analyzer), obtained during the measurement of γ radiation at the surface of two groups of soils. Individual monochromatic lines, belonging to different radioisotopes, are seen on the spectrogram in the form of photopeaks (Fig. 2).

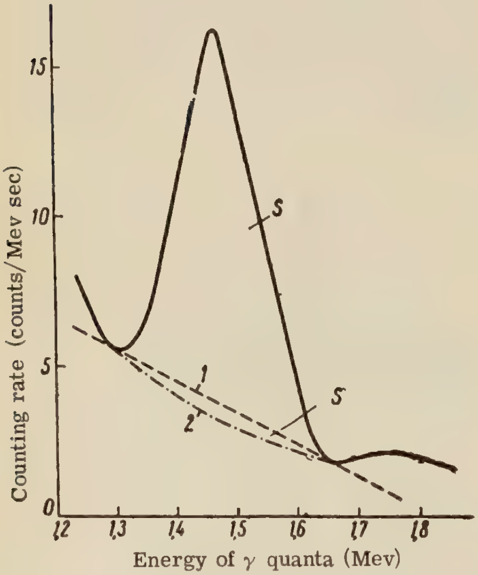

Fig. 3. – Diagram illustrating the method of determining the area subtending the potassium-40 photopeak, as exemplified by Figure 2.
1 – approximate determination of the photopeak; 2 – accurate determination of the photopeak.

The scintillation spectrometer used by us had the following main elements: a scintillating crystal – a sodium iodide crystal, activated with thallium, 80 mm in diameter and 60 mm high; an FEU-24 photoelectronic multiplier; and a count amplitude analyzer – a multichannel (128 channels) AMA-3c amplitude analyzer (1). The energy resolution of the spectrometer for a quantum energy E_0 = 0.66 Mev is 13%. The instrument spectra shown in Figure 2 were obtained with this γ spectrometer.

Various methods can be used to convert the instrument spectra into the unknown concentrations. One of the possible means consists in the conversion of the instrument spectrum into the energy composition of quanta for each radiation source (determination of direct and scattered radiation) and then the determination from these data of the parameters of the radiation source (concentration, distribution with depth). It is also possible to divide the instrument spectrum into components, determined by the self-determining radiations of individual isotopes with a subsequent transition to parameters of the radiation source.

Considering that potassium is distributed sufficiently evenly in the upper soil layer (3), its concentration was determined from measurements of the area under the photopeak S with E_0 = 1.46 Mev, which is proportional to the total number of quanta with this energy which have passed the detector in unit time. S was

Table 1

Relative change of the area subtending the photopeak, depending on the height above the soil surface

Flight altitude h, m	0	10	20	40	60	80	100
Reduction coefficient, K	1.0	1.3	1.5	2.0	2.5	3.2	4.0

determined with a certain insignificant error δS (Fig. 3). Let us note that the contribution of γ quanta from radium $E_0 = 1.76$ and $E_0 = 1.38$ Mev and thorium with $E_0 = 1.62$ Mev to the photopeaks of potassium-40 is small (5%-8%).

The unknown potassium concentration ϵ is determined from the formula $\epsilon = \alpha(h) \cdot S$, where $\alpha(h)$ is a coefficient which depends on the flight altitude and the parameters of the instrument. This coefficient is practically independent of the atomic composition of soils within an energy range from 0.3-3.0 Mev. The method of determining the concentration of a radioactive element from measurements of the area under the photopeak should be called the method of direct (non-scattered) rays. Let us note that the method of direct rays is very convenient, provided the scintillation detector is sufficiently sensitive and has a high enough resolving power, and makes it possible to determine the unknown concentrations of radioelements in the soil directly.

We measured the γ radiation from soils with the detector at the soil surface as well as from an airplane. The information on the areas subtending the photopeak of potassium obtained from an airplane depends on the flight altitude h. In fact, as long as the radiation perceived by the detector originates from a zone with dimensions commensurate with the length of the free path of a quantum in the absorbing medium, the area S is proportional to the average content of the radioelement in this zone. When the radiation detector is installed directly at the soil surface, the area subtending the photopeak of potassium-40 on the spectrogram characterizes the average content of the radioelement in a hemisphere with a radius of 15-20 cm.

As the height increases, area S decreases in conformity with the law $S(h) = S(O)\ \Phi(\mu h)$, where μ is the absorption coefficient of γ rays in the air and $\Phi(x)$ is the tabulated King function. There is half as much S(O) for the γ radiation of potassium-40 S(h) at a height of h = 40 m and half that at a height of h = 100 m. The rate of decrease S(h) is shown in Table 1, where the coefficient $k = 1/\Phi(\mu h)$ is given for the potassium-40 radioisotope.

It must be noted that the zone of averaging changes depending on the height h. Calculations show that the zone for which the average concentration of potassium in the soil is determined is in the shape of a circle with a radius equal to the height h and a thickness of 15-20 cm at heights from several meters to 100-150 m. At the flight altitude h the zone of averaging has the form of a strip 2h wide; the length of the strip is determined by the distance covered by the airplane during the time of counting measurement.

To convert the known value S into the potassium concentration in the soil we must know coefficient $\alpha(h)$. There are several possible ways of finding $\alpha(h)$: such as from experimental flights over an area with a known potassium content; from theoretical calculations from the given parameters of the equipment; and from a combination of both these methods.

We determined $\alpha(h)$ in the following manner. We took soil samples in an area with linear parameters of several meters and an even potassium distribution and determined the potassium concentration in the soil from the results of laboratory analysis; then by means of the instruments to be used later we measured the value of S at h = 1 m and found the relationship between this value and the average concentration of potassium in the soil. We obtained the magnitude of function $\alpha(h)$ from S(h = 1 m) by calculation. The foregoing method of calibrating the instruments is simple and ensures sufficient accuracy, since it takes into account the absorption of γ rays in the screening material (walls of the instrument, of the airplane, etc.). Let us note that the geometry of direct γ rays remains practically unchanged at various heights.

3. We measured potassium concentration from the airplane in three soil zones: a) gray forest soils and podzolized and leached chernozems in the central European SSSR; b) chernozems of the Ukraine; and c) chestnut soils of the Ukraine. We measured the energy composition of γ quanta at strictly fixed flight altitudes, usually of 25-35 m, on different flight routes crossing the selected soil groups. The flight routes were selected in accordance with soil maps: according to sheets M-36 and L-36 (published in 1949 and 1955) of the 1:1,000,000 State Soil Map of the USSR for the Ukraine and the 1:2,500,000 soil map of the European SSSR, published in 1947, for the RSFSR.

The length of the flight route was determined on the one hand by the geometrical dimensions of the soil group studied, and, on the other hand, by statistical requirements (1000-2000 counts in a potassium-40 photopeak). This length usually varied from 20-80 km.

The results obtained for 13 flight routes are presented in Table 2. These data characterize the average potassium content in the surface soil horizons. Let us note that the data in this table were calculated in grams of K_2O per gram of all substances contained in the upper soil layer (including vegetation, water, humus, etc.). The accuracy of these data, in our estimation, is not less than 10%-12%. The main reasons for the observation errors are: a) an error in the determination of the area subtending the photopeak of potassium-40, which consists in purely statistical errors, possible instrumental errors, and the assumption illustrated in Figure 3, and which amounts to ~5%-7%; b) an error associated with an inaccurate knowledge of the flight altitude and its changes en route, which amounts to 3%-5%; c) an instrument calibration error in the control area, causing a systematic error in the calculation of the potassium concentration in soil, of ~3%-5%.

The data in Table 2 lead to the following conclusions: a) the potassium content in the soil groups studied varies from 1.0% K_2O in the slightly and moderately podzolic sod soil (Profile 10) to 1.9% in the slightly humic, moderately thick southern chernozem and the light-gray and gray podzolized forest soil (Profiles 5 and 12). As a rule the potassium

Table 2

Potassium (K_2O) content in the surface layers of soils in individual regions of the Ukraine and the RSFSR

Profile No.	Soil group	Texture	Geographical location of the sampling route	K_2O content, % of weight
1	Northern, moderately humic, thick and very thick chernozem (Ch_2'''')	Clay and fine clay loam, silty	Ukraine, city of Savran' on the Yuzhnyy Bug River, Yermilovka station	1.7
2	Ordinary, moderately humic, thick chernozem (Ch_2''')	Clay and fine clay loam, silty, on loess	Ukraine, Mikhaylovka village, 15 km northwest of Berezovka, Krichunovo	1.4
3	Same	Clay and fine clay loam, silty	Ukraine, Dnepropetrovsk airfield	1.7
4	Ordinary, moderately, and slightly humic, moderately thick chernozem (Ch''_{2+1})	Clay and fine clay loam, silty, on loess	Ukraine, Lozovatka village, on Ingul River, Novyy Bug	1.7
5	Slightly humic, moderately thick southern chernozem (Ch''_1)	Same	Ukraine, Novo-Poltava kolkhoz (20 km southeast of Novyy Bug), Verovka village (15 km northwest of Berislav)	1.9
6	Slightly humic, moderately thick(solonetzic) southern chernozem (Ch''_1)	Silty medium clay loam on loess-like deposits	Ukraine, Berislav on Dnepr River, Luparevo village on Bug estuary	1.8
7	Dark-chestnut (K_2)	Same	Ukraine, Parutino on Bug estuary, Koblevo on Tiligul' estuary	1.8
8	Slightly and moderately podzolic sod (P^s_1)	Clay and fine clay loam	RSFSR, Urazmet'yevo village on Uren' River (15 km southeast of Bogorodsliye), Uzyar village on Osh'ya River (25 km northwest of Yanaur River)	1.2
9	Same	Same	RSFSR, Kol'tsovo airfield, Sverdlovsk Oblast'	1.2
10	Same	Sandy and sandy loam soils	RSFSR, Men'shchikovo village, 35 km northwest of Mukhtolovo station, Krasnaya Gorbatka on Ushna River	1.0
11	Light-gray and gray podzolized forest soil (F_1)	Clay and fine clay loam	RSFSR, Umyak village on Vyatka River, Lapshevo on Kama River	1.4
12	Same	Same	RSFSR, Kazan'	1.9
13	Same	Med. and coarse clay loam (primarily sandy-clay)	RSFSR, Tsivil'sk on Tsivil' River, Knyaginino on Imza River	1.4

Table 3

Comparison of data on the potassium content in the upper soil layer

Soil group	Layer thickness, cm	Ignition losses, %	K_2O content in the soil, % of weight
Moderately humic, moderately thick chernoz.			
a) according to Sobolev (4), Table 23	0—14	12.5	2.0
b) soil Profile 4	0—15	—	1.7
Dark-chestnut soil			
a) according to Sobolev (4), Table 29	5—25	11	1.9
b) Soil Profile 7	0—15		1.8

content increases from slightly and moderately podzolic sod soils to gray forest soils and to chernozems; b) the potassium content is higher in clay and fine-textured clay loam soils within a given soil group than in the sandy and sandy loam soils (Profiles 8, 10, and 12, 13), which agrees with known facts (2, 3); c) the average potassium concentrations in one and the same soil group fluctuates by 30%-35% within the soil zones studied.

It is difficult to compare our results with those of other investigations because, first of all, the data on the potassium content of soils, found in the literature, refer to relatively large areas and cannot be considered as average for a soil zone, and, secondly, these data are usually given for ignited soil samples (humus- and carbonate-free). In Table 3 we compared the data of Sobolev (4) on the potassium content in moderately humic, moderately thick chernozem in the Ukraine and the dark-chestnut soil of the southern Ukraine with the data given in Table 2, as an example. Ignition losses are taken into account in Table 3.

If we keep in mind the foregoing remarks on possible observation errors and on the distribution of data for a limited area over a large area, we must consider the agreement between the determinations satisfactory.

The results of our studies show that the method of measuring the potassium content in the upper soil layer from direct radiation is of practical interest in the estimation of the average contents both for large areas (airplane observations) as for limited soil areas (surface observations).

The foregoing radiometric method (or its modification) can also be used to determine the content of two γ-radiating radioisotopes in soils and rocks.

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FIELD METHOD OF DETERMINING NITRATES IN NON-SALINE SOILS

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Having worked a number of years under field conditions, we found it necessary to make mass determinations of nitrate nitrogen in soils. The classical method of Grandval-lajou (nitrate determination with disulfophenolic acid) did not satisfy us because of its low productivity. We were not able to evaporate a large amount of soil extracts under field conditions.

The literature contains descriptions of several simple and rapid methods of determining nitrates, by means of brucine, strychnine, and salicylic acid, for instance, or by the reduction of nitrate to nitrite or ammonia and the subsequent determination of the reduced products. However, as we become more closely acquainted with the foregoing methods, we were not satisfied with either of them for various reasons. The brucine method gives satisfactory results only if certain conditions are strictly adhered to during analysis. In addition, it is applicable to a very limited range of nitrate contents in the solution (1). The hydrostrychnine method is very sensitive, but one must remove calcium, magnesium, iron, phosphorus, and other ions, which are always present in soil extracts, from the solution, and the introduction of complex-producers always complicates analysis (3). The rapid colorimetric test-tube method with salicylic acid requires the preliminary evaporation of the extract (6). During the reduction of nitrates to nitrites in an acid medium (with the determination of nitrates according to Griss), a partial loss of nitrate nitrogen is unavoidable, while the method developed by a group of authors (8) for reducing nitrates to nitrites in an alkaline medium is not simple, since calcium, magnesium, and ammonium must be removed from the extract. When reducing nitrates to ammonia, the latter must be distilled (5, 7), which eliminates the possibility of using this method under field conditions.

We selected the method of Zamyatina (4) for determining nitrates by means of indigo as the simplest and most rapid method. But after verification under field conditions (in 1955 and 1956) we were forced to drop this method because of its low sensitivity and unsatisfactory reproducibility.

Not having found a method which would satisfy us, we developed (in 1957) a modified method of determining nitrates with disulfophenolic acid. This is a test-tube method which does not require preliminary evaporation of soil extracts. We used it for 4 years and feel that we can recommend it as a quick method for the field (Table 1). The sensitivity of this method is low, but fully sufficient for the study of such problems as the influence of various agricultural practices on nitrate accumulation, for instance, and the study of the dynamics of nitrates during the growing period.

Development and Verification of the Quick Method

The development of the quick method with disulfophenolic acid was based on our observation that at a given concentration of reagents, the ratio between the volumes of the extract and disulfophenolic acid, the color intensity of the solution on heating the mixture is approximately the same as during the evaporation of the same volume of extract at the same concentration.

For the sake of simplicity and accessibility we developed a method applicable to ordinary chemical test tubes (15 cm long and 15 mm in diameter). For convenience and safety it is desirable that the volume of the solution to be subject to colorimetry be not greater than half of the volume of the test tube, i. e., 10 ml.

In developing the method we studied the following: 1) The concentration of the reagents; 2) The ratio between the volumes of the extract to be analyzed and the reagents; 3) The time it takes to heat the solution; and 4) The heating temperature.

In following the method described by Gedroyts (2) for preparing the disulfophenolic acid reagent and in verifying the 1:0.5, 1:1, and 1:1.5 ratios between the volumes of the extract to be analyzed and the reagent, we established that the best coloration is obtained at a ratio of 1:1. Coloration does not develop with a lesser volume of disulfophenolic acid, while at a greater volume the intensity of the coloration does not increase substantially and it becomes necessary to increase the volume of alkali to neutralize the acid, which is undesirable.

Table 1

Comparison of the test-tube quick method of determining nitrates with the disulfophenolic acid method of Grandval-Lajou

Content of nitrates in various soils			Content of nitrates under various land uses			
Soil	mg N/kg, accord. to the method		Landuse	Depth, cm	mg N/kg, accord. to the method	
	Orig-inal	Test-tube			Orig-inal	Test tube
Chernozem (Kursk)	14,1	16	Plntd.area	0—10	4,0	4
Chernozem (Bargoy)	2,3	<4	"	10—20	4,5	6
Meadow-chernozem (Chita)	9,7	10	"	20—30	6,0	<4
Chestnut (Buryatiya)	1,4	<4	Fallow	0—10	50,5	64
				10—20	9,5	8
Gray forest (Buryatiya)	13,3	12	"	20—30	4,0	4
Meadow-alluvial (Buryatiya)	2,7	<4	Virgin	0—10	4,5	4
Red earths (Anaseuli)	12,4	12	"	10—20	4,0	6
			"	20—30	3,0	4

Note: Comma represents decimal point.

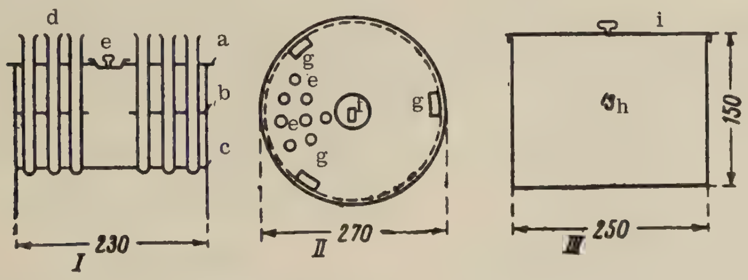

Fig. 1. - Water bath with the test-tube rack.

I - View of the rack in lateral cross section. a - upper surface with 60 openings 17 mm in diameter; b - middle surface with 60 openings 17 mm in diameter; c - lower surface with 60 openings 12 mm in diameter; d - test tube. II - Rack from above. e - openings for the test tubes; f - heating plate; g - rack tripod. III - Water bath. h - bath; i - cover.

Table 2

Scale of samples solutions for colorimetry

Flask and test tube number	1	2	3	4	5	6	7	8	9	10	11	12
ml of sample solution 3 in a 100 ml flask	4	6	8	10	12	14	16	18	20	15	30	40
mg of N/1000 g of soil	4	6	8	10	12	14	16	18	20	15	30	40

A decrease in the concentration of sulfuric acid in the reagent and an increase in the content of phenol by its addition to the reagent and extract mixture lowered the sensitivity of the method.

With a 1:1 ratio between the volumes of the extract and the disulfophenolic acid solution and the fixed volume of the colorimetric liquid in the test tube (10 ml), the concentration of alkali (NaOH) must be 30%.

The study of the influence of the heating temperature on development of coloration showed that no coloration occurs at room temperature. Heating the mixture in a boiling water bath and over a flame (until the beginning of boiling) produced the same results. Heating in a boiling water bath for 3, 10, and 30 min (after the beginning of boiling) had the same effect on color development.

For the convenience and rapidity of analysis we recommend that a special water bath, which would hold 60 test tubes, be used for heating the solution in the test tubes.

To obtain transparent soil extract without turbidity we do not extract the nitrates from the soil with water, but with a 0.05% solution of potassium sulfate.

Analytical procedure. One milliliter of the extract is micropipetted in each of a series of chemical test tubes, which are colorless, of the same diameter, and marked at 10 ml. One milliliter of disulfophenolic acid (reagent 1) is added to each test tube with a burette. The solutions are mixed by carefully rotating the test tubes. All the test tubes with the tested and sample solutions are placed into the rack of the water bath (Fig. 1). Then the rack with the test tubes is carefully lowered in the boiling water of the bath. The water level in the bath must be slightly higher than the level of the liquid in the test tubes. As soon as the water in the bath begins to boil again, the time at which boiling begins is recorded. The rack with the test tubes is withdrawn from the bath after 3 min. After the test tubes are cooled, alkali (reagent 2) is added to each from a burette to neutralize the acid. Alkali is added carefully in small amounts and the mixture is shaken each time. By the end of neutralization the alkali is added in drops until a stable yellow color appears. The cooled solution in the test tubes is brought to 10 ml with water, shaken, and subject to colorimetric analysis according to the scale of sample solutions.

Scale of Sample Solutions for Colorimetry

Increasing amounts (from 4-40 ml) of a sample nitrate solution (reagent 3) are poured into 12 consecutively numbered 100 ml volumetric flasks. The flasks are brought to volume (10 ml) with a 0.05% solution of potassium sulfate. To prepare the working scale of sample solutions for colorimetry 1 ml of solution is taken from each flask and placed into 12 test tubes. Then 1 ml of disulfophenolic acid is added to the test tubes, the mixture is stirred, and so on as for the test solutions.

If the colors of the test and sample solutions are weak, they are compared (examined) from the top of the test tube, whereas if the color is intense it is examined from the side through a comparator. With enough experience an analyst can distinguish the color during colorimetry with an accuracy of about one-fourth of an interval between neighboring tests tubes, i. e., an accuracy of about ±10%.

If the content of nitrate nitrogen in the soil exceeds 40 mg/kg of soil, the extract is diluted a corresponding number of times and the determination is repeated. If it becomes necessary to determine small amounts of nitrate nitrogen (less than 4 mg N/kg of soil), the analysis is made in larger test tubes. Two to three milliliters of the extract are taken and an equal volume of disulfophenolic acid and corresponding amounts of the other reagents are added to it.

Reagents and glassware. 1. Disulophenolic acid. Seventy-five grams of pure crystalline phenol are mixed with 500 ml of concentrated sulfuric acid (specific gravity, 1.84) and heated in a boiling water bath for 6 hrs. A long (about 1 m) glass tube is inserted in the reflux condenser of the stoppered flask.

2. 30% solution of sodium hydroxide (NaOH).

3. Sample of nitrate solution. A 0.1444 g sample of chemically pure potassium nitrate (KNO_3) is diluted in a 1-liter volumetric flask with a 0.05% solution of potassium sulfate; the liquid is brought to volume (1000 ml) with the same solution. One milliliter of the sample solution contains 0.02 mg of N.

4. 0.05% solution of potassium sulfate for removing nitrates from the soils.

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SEMI-AUTOMATIC PIPETTE

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Much time is spent in the laboratory on measuring off and decanting solutions during all types of analyses. In 1954, we combined two processes: the filling and decanting of solutions by means of a 4-way stopcock and pipettes instead of cylinders for increasing the accuracy of measuring off liquids. Such a device was conditionally designated as a semi-automatic pipette.

The arrangement and operating procedures of the semi-automatic pipette can be seen from Figure 1.

The flow of liquid is regulated by means of a screw clamp, which is arranged in such a way that the liquid in one of the pipettes flows out before another pipette begins to fill. The screw clamp is set beforehand. The accuracy with which the liquid is measured off can be seen from Table 1.

The true volume was determined by the formula: Vt = Wt x Ct, where Vt is the volume of the vessel at a given temperature; Wt is the weight of water at the same temperature; and Ct is a factor, the value of which was taken from the "Handbook of Chemistry" Vol. 3. p. 1133-1134 (GKHI, Moscow, 1952).

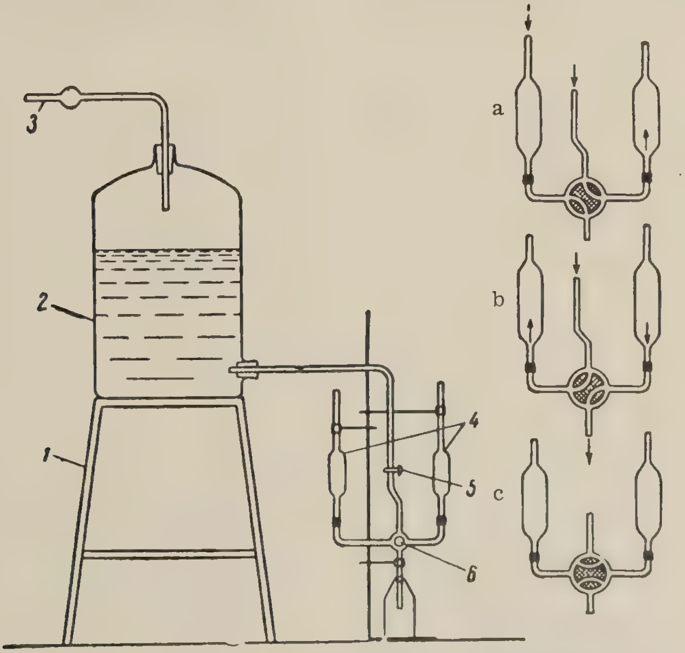

Fig. 1. - Semi-automatic pipette
1 - support; 2 - vessel with the liquid; 3 - calcium chloride tube; 4 - pipette; 5 - screw clamp; 6 - 4-way faucet (a, b - working position, c - neutral position).

Table 1

Comparative evaluation of the semi-automatic pipettes used from measuring off liquids (volume, ml)

Pipette capacity	Capacity at a temperature of 20°C	Found during calibration after the liquid was brought to a temperature of 20°C	Absolute error of the peipette, ml ±	Mean error M		Allowable deviations from the nominal capacity[a]
				ml	%	
250	250	250,6125	+0,6125	±0,079	0,032	±1,0
125	125	125,2288	+0,2288	±0,067	0,050	+0,4[b]
50	50	49,9270	–0,0730	±0,074	0,151	±0,3
10	10	10,1619	+0,1619	±0,040	0,39	±0,2

[a] The allowable deviations were taken for pouring cylinders. See "Handbook of Chemistry," Vol. 3, p. 1136 (GKHI, 1952).

[b] Deviations are taken from 100 ml cylinders.

Note: Comma represents decimal point.

Because of the simplicity of the semi-automatic pipette, it can be manufactured by any glass blower. The openings in the stopcock must be of the same diameter and arranged strictly at an angle of 90°. The pipettes are made in conformity with the volume of the side branches (tubes) of the 4-way stopcock in such a manner that the upper meniscus fit the narrow part of the pipette. In measuring off large amounts of liquid (250 ml and more) the openings in the stopcock and in the lower part of the pipettes must be of a large diameter.

The use of the semi-automatic pipette in mass analyses saves a lot of time in filling it with the liquid and measuring off the set amount of solution with the required accuracy. The semi-automatic pipette is used at the Laboratory of Agricultural Chemistry of the Krasnodar Agricultural Scientific-Research Institute of the All-Union Scientific-Research Institute of Oil-Bearing and Ester-Oil Bearing Crops, and a number of other institutions.

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METHOD OF CONTROLLING INFLUXION[1]

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G. N. Vysotskiy was the first to consider influxion, having suggested this term. Few were concerned with the experimental study of this important and interesting problem when his work appeared. The existing methods of studying soil moisture are unsuitable for the study of influxion.

In 1957 we tried to apply the tracer method, used in hydrogeological investigations of the direction and velocity of subsurface flow, to the study of influxion.

Dyes (fluorescein, fluoranthone, eosin, Congo red, methyl blue, etc.) or various salts (mostly table salt) are usually used as tracers to "tag" the water of subsurface flow. The movement of "tagged" water is determined by various methods. Thus, for instance, when table salt is used the amount of chloride in the water is determined by titration with silver nitrate.

For our purpose it was necessary to select a tracer which would not be adsorbed by the soil, would not affect its water-physical properties, would be detectable by the simplest means, and would be generally available. Verification showed that dyes are less suitable for controlling influxion than salts. However, the possibility of using salts is rather limited. The use of sodium chloride, for instance, when there is an excess of sodium ions, leads to the replacement of exchangeable calcium by them. This sharply decreases the water permeability of the soils and changes the experimental conditions.

This fact excluded the use of table salt as a tracer in spite of the fact that laboratory and field experiments revealed a number of advantages of this method. The fixation of chloride ions in the soil by means of silver nitrate made it possible to follow visually in the pit, without taking samples, the paths of the table salt solution, and to photograph the profiles. After spraying the surface of the profile with a solution of silver nitrate, clear whitish spots of silver chloride appeared along the path of the "tagged water".

To eliminate this disadvantage we decided to use calcium chloride, which is relatively easily obtainable at sodium carbonate factories, where it is a waste product. As we know, calcium chloride is easily dissolved in water.

The presence of calcium does not worsen the water-physical properties of the soil. By experimentation we selected the optimum concentration of calcium chloride and silver nitrate solutions so that the precipitation of silver chloride be sufficiently intense and that the whitish spots along the path of tagged water be clearly visible. It proved that a 5%-10% solution of calcium chloride and a tenth normal solution of silver nitrate ensure the formation of sufficiently clear whitish spots, which are easily fixed on a photographic film within the humus and intermediate horizons. A 5% concentration of calcium chloride is sufficient for visual observations and mapping.

The operating method was elaborated during laboratory and field tests. To control influxion, areas 2-5 m^2 are flooded. The area is diked or enclosed in a special frame. The amount of solution used in an area depends on the experimental conditions. We can determine the rate of water infiltration thereby.

To determine the paths of the solution in the soil the area is excavated in 0.2-0.5 m layers. The upper layer is removed, the surface is thoroughly cleaned with a sharp spade and hoe, and then the entire open surface is sprayed with the silver nitrate solution.

Investigations showed that in order for silver chloride to precipitate intensely the silver nitrate solutions must be sprayed on the soil surface and not atomized. Silver chloride precipitates more intensely when the solution is sprayed in large drops and less solution is used. A bottle with a small glass tube in the stopper is most suitable for spraying. In doing this 200-250 g of the solution are needed per 1 m^2.

All the details of the open surface (roots, cracks, krotovinas, earthworm channels), as well as the whitish spots of silver chloride along the paths of the solution, are plotted in scale on a plane-table. To facilitate mapping, the surface is divided into squares with pegs. After the first layer is mapped, the pit is excavated another 0.2-0.5 m, the surface is cleaned, sprayed, etc. The last layer, where there is no visible silver chloride precipitation, can be used to take samples for control, for making the water extract, and for titration.

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[1] By influxion we mean the infiltration of surface oisture into the soil, primarily through cracks and rge pores.

The method was tested in the field in Veliko-Anadolye in July 1957. Areas 5 m² were flooded in a 16-year old oak stand in forest No. 32 at the Mariupol' Experimental Forest Station.

There was one freshly-cut oak stump and the remains of a small, semi-rotted stump in the area. The underbrush was sparse, 50-60 cm high, consisting of yellow acacia (2 specimens), and red dogwood (1 specimen), hawthorn (1 specimen), honeysuckle (2 specimens), Tatarian maple (1 specimen), and self-seeded oak (2 specimens). The cover was dead. The oak leaf litter was 1-2 cm thick. The soil was an ordinary leached, fine clay loam chernozem on loess-like yellow-brown clay.

H[2] (A) 0-45 cm. Dark-gray, fine clay loam, damp, compacted, granular, with tree roots. The transition is gradual.

HPK (B_1) 45-85 cm. Dark-gray with a brownish tinge, damp, compacted, blocky-granular, with root passages. The transition is hardly noticeable.

HPK (B_2) 85-110 cm. Gray-brown with an uneven humus coloration, damp, blocky with krotovinas, rare humus tongues.

PK (B_3) 110-150 cm. Brown, moist, compact, blocky with root passages, finely porous with krotovinas. Effervesces from HCl from a depth of 125 cm.

PK (C) 150-300 cm. Brown, damp, compact

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[2] The first designations of the horizons are according to Sokolovskiy.

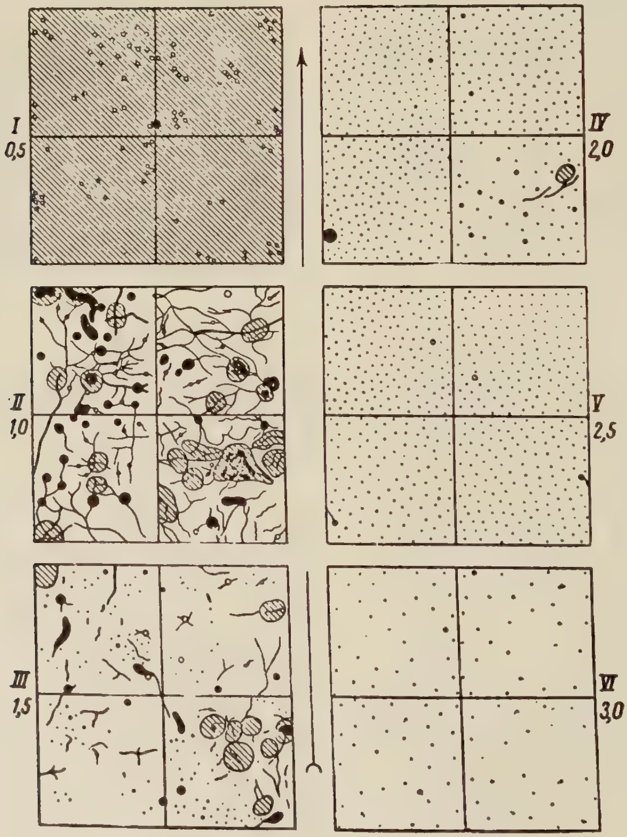

Fig. 1. - Maps of horizontal influxion profiles for depths of:
I - 0.5 m; II - 1.0 m; III - 1.5 m; IV - 2.0 m, and 3 m. Hachures show the paths of the solution; the dark areas show krotovinas; fine, wavy lines indicate cracks in the soil; light circles indicate roots; dots indicate earthworm channels.

with root passages, almost no whitish spots, an old krotovina on top, carbonates are in the form of tubes, rarely concretions, increasing in number with depth.

The area was flooded with about 2000 liters (400 mm) of a 5% solution of calcium chloride. Flooding took a day since the water had to be brought in barrels by horse from a distance of several kilometers. The saturated calcium solution was prepared in situ and poured into the water barrel, mixed and then used for floodings. Excavation was started 1 day after flooding the area and completed on the fifth day. Each 0.5 m horizon was mapped to a depth of 3 m, where no signs of the penetration of the solution were found.

Complete wetting occurred only to a depth of 1 m. There was influxion in the second meter, while the solution did not penetrate at all into the third meter of the soils (Fig. 1).

The depth of complete soil wetting could have been greater if excavation were started a certain time after flooding and not immediately. This is evidenced by the high moisture content of the upper soil layer, which exceeded the field moisture capacity (Table 1). However, this is of importance only during investigations on the pattern of infiltration. To study influxion, excavation must be started immediately after flooding, since the penetration of water into the soil through cracks apparently occurs very rapidly.

Table 1 gives the calculated total moisture content before and after flooding. Comparison shows that within the area the total moisture content increased primarily in the upper 2 m by about 300 mm. The remaining 100 mm of the solutions was lost on lateral spreading beyond the limits of the area and evaporation. The tests showed that the method is suitable for controlling influxion to clarify the problem of the ways and nature of water filtration in soils.

It is interesting to note that the highly-permeable forest soil has a great water-holding capacity as a result of which 400 mm of the solution (normal annual precipitation) are fully absorbed. Influxion was found in the second meter of the soil, but was comparatively low, however.

It must be noted that the foregoing method makes it possible not only to control influxion, but to determine it. If influxion is greater than it was in our case, the amount of water held back in the completely wetted soil layer (and spreading) must be deducted from the total amount of solution used for flooding. The amount of water held back is determined from the change in the moisture content of the soil ($M_A - M_B$), by measuring the moisture content of the soil by layers before and after flooding. The difference between the amount of water added and that held back will be equal to the loss of water by influxion and evaporation.

Physical evaporation from the soil surface during several days can be determined directly with evaporimeters. It can be reduced to the minimum and neglected altogether if the area is covered with tarpaulin after it is flooded. The loss of water by plant transpiration can be neglected, since roots are removed from the upper soil layers the first day of excavation. In addition, the method of influxion control makes it possible to study the distribution of cracks, animal channels, and roots in soil, and to clarify their hydrological importance.

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Table 1

Calculation of the change in the total moisture content of soil in the area

Layer, m	Bulk density, g/cm³	Average moisture, % of dry weight		Total moisture content, mm	
		Before	After	Before	After
		Total			
0—0,25	1,05	18,6	36,4	48,8	95,5
0,25—0,50	1,05	17,4	37,2	45,7	97,7
0,50—0,75	1,25	16,4	34,6	51,3	90,8
0,75—1,00	1,40	16,4	32,8	57,4	114,8
1,00—1,25	1,45	16,2	29,8	58,7	108,0
1,25—1,50	1,50	15,0	23,5	56,3	88,2
1,50—2,00	1,55	15,2	17,8	119,8	137,9
2,00—2,50	1,55	14,6	15,4	113,2	119,4
Total	—	—	—	549,2	852,3

Note: Comma represents decimal point.

ESTABLISHMENT OF THE TIME OF SOIL MOISTURE SAMPLING FOR THE DETERMINATION OF FIELD MOISTURE CAPACITY

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The Hydrometeorological Service of the USSR has adopted a single method of determining the minimum field moisture capacity, which is also used by the Hydrometeorological Service Administration of Central Asia (3). At present there are various opinions about the time of soil moisture sampling after flooding areas in various soil groups.

According to the instructions to hydrometeorological stations for the determination of the agricultural-hydrological properties of the soil (3), soil moisture sampling for the determination of minimum field moisture capacity is done in the following manner: the first sample is taken 3-4 days after the flooding of sandy and sandy loam soils and 6-8 days after the flooding of clay loam and clay soils. The second determination is made the second day after the first.

The All-Union Scientific-Research Institute of Cotton Growing (13) takes soil moisture samples at other times after the flooding of sierozem and meadow soils of the sierozem belt to determine their minimum field moisture capacity. The first moisture determination is made 3-5 days after the flooding of fine-textured (clay and clay loam) soils and 2-3 days after the flooding of coarse-textured soils (sandy, sandy loam, and coarse clay loam).

The Hydrometeorological Service Administration of the Uzbek SSR began its systematic determinations of minimum field moisture capacity in 1955 according to the method of the All-Union Scientific-Research Institute of Cotton Growing. Thus, soil moisture samples for the determination of minimum field moisture capacity of fine-textured soils were taken by the Hydrometeorological Service Administration of the Uzbek SSR 3 days earlier than specified in the instructions of the Hydrometeorological Service.

To elaborate the time of sampling fine-textured typical sierozems, the Agricultural-Meteorological Station Boz-su conducted special experiments in 1959 on the time of moisture sampling for the determination of field moisture capacity. Each area of 2 x 2 m was flooded with 1747 liters of water.

The experiments were replicated 5 times. All areas were flooded at the same time. After flooding planks were placed on the area and covered with tarpaulin. Corn stalks were strewn over the tarpaulin in a layer 50 cm thick. Soil was placed on the edges of the tarpaulin.

Soil moisture samples were taken at 7 p. m. after which the areas were carefully covered again. The first moisture sample was taken

Table 1

Soil moisture, %

Depth, cm	After (days)		After (days)	
	3	4	5	6
0—10	28,0	27,3	26,7	27,1
10—20	23,9	21,8	23,1	21,9
20—30	20,4	19,4	21,3	20,1
30—40	21,3	21,1	21,4	20,7
40—50	20,3	20,2	21,1	20,3
50—60	20,4	20,0	20,6	20,6
60—70	18,7	19,6	19,8	20,2
70—80	18,2	19,0	18,3	18,8
80—90	18,0	18,7	18,9	17,8
90—100	18,7	19,5	18,4	18,0

Note: Comma represents decimal point.

3 days after flooding; the second after 4 days; the third, after 5 days; and the fourth, after 6 days. The samples were taken from each 10 cm layer to a depth of 1 m. Minimum field moisture capacity was determined for the upper 1 m only, because the main part of the root system of cotton is concentrated there (2).

To determine the water penetration of the soil, rulers were set up on all the areas after flooding, from which the thickness of the water layer infiltrating the soil was determined. It proved to be: 4-5 cm in the first hour: 2-3 cm in the second hr; 2-3 cm in the third hour, 2 cm in the fourth hour; 2-3 cm in the fifth hour; and 1-2 cm in the sixth hour. The results of soil moisture determinations in the flooded areas are presented in Table 1.

In examining Table 1 we can see that a moisture equilibrium was reached in the soil as early as 3 days; its distribution in the soil 4.5 and 6 days after flooding showed that it remains practically the same as on the third day. Consequently, the first soil moisture sample in sierozem must be taken 3 days after flooding and the second (control), a day later.

These conclusions indicate that it is possible to save time during the determination of minimum field moisture capacity. The probability of errors in the determination of minimum field moisture capacity as a result of evaporation from the surface, which could take place if the areas are not properly covered, could be reduced thereby.

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CHRONICLE

THE TRAINING OF SOIL CHEMISTS[1]... Letter to the Editor

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The modern progress in natural sciences is due to a great extent to the development of physical and chemical sciences. Physics and chemistry not only explain many phenomena and processes taking place in nature, but also give the investigator perfected instruments, and accurate and sensitive methods which permit him to penetrate the intermost secrets of nature.

Soil science, as one of the branches of natural sciences, is not an exception. And if at the time when V. V. Dokuchayev created the principles of soil science as an independent scientific discipline the predominant method was that of comparative geography, in the subsequent decades soil science used the achievements of theoretical and experimental physics and chemistry, even though it still lags behind other natural sciences, including biology, in this respect.

The study of the formation and the composition of organic and mineral portions of the soil and their interaction requires various methods, accurate and comprehensive observations, and complicated analyses of data.

We cannot deny the fact that progress has been made in the last years in methods of soil investigation. The development and expansion of chemical and physical methods in soil science proceeds at the present time in two main directions, corresponding to the principle tasks of soil scientists. Because of the considerable growth of cartographic soil evaluation, and meliorative and agricultural-chemical work, the need for rapid methods of soil and plant analysis, which would be suitable for mass determinations, has increased sharply. This led to the appearance of a series of methodological investigations. Considerable work has already been done in this field, but we still have to do a lot more.

On the other hand, the most modern methods in physics and physical chemistry are being introduced more and more into genetic soil investigations. Without these methods it would be impossible to solve many problems in soil chemistry, especially those related to the texture, structure, and transformation of mineral and organic substances.

The development of the foregoing directions would be impossible without a wide network of soil chemistry laboratories and trained soil chemists. The importance of systematic chemical soil investigations is tremendous and is dictated by the development of the entire agriculture of our country.

The main task of soil science, ensuing from the resolutions of the XXI session of the Communist Party of the USSR and the plenums of the Central Committee of the Communist Party of the USSR on problems of agriculture, consists of the development of theoretical bases and practical methods for increasing agricultural production on the basis of an increase of soil fertility and the rational utilization of the land resources. The resolutions of the XXI session of the Communist Party of the USSR call for a sharp improvement in the utilization of land as the principal means of agricultural production, and a considerable increase in the production of mineral and organic fertilizers. In the light of these resolutions it is imperative that the detailed soil inventory (systematization and site quality) be speeded up, as well as the determination of the requirement of soils for fertilizers (including micronutrient fertilizers), liming, and meliorative measures. The necessity for a comprehensive investigation of soil in the Republic is also called for by the Nature Protection Law in the RSFSR, adopted by a session of the Supreme Soviet of the RSFSR on October 27, 1960.

The fulfillment of these tasks requires additional efforts from the soil scientists for the creation and expansion of agricultural-chemical soil laboratories and the conduct of mass analyses. The scale of the necessary work is exceptionally large, which we can easily show by an example.

The investigation of the non-chernozem belt requires the determination of the actual reaction of the soils, their hydrolytic acidity, and their potassium, phosphorous, and nitrogen content. To characterize the soils of even a small territory, covering only 300,000-400,000 hectares, several thousand samples must be analyzed. When farming is conducted rationally and the crop yield is steadily high year after year, soil analysis must be repeated regularly every 4-5 years. This shows how large the volume of analytical work is which must be fulfilled in the nearest future by soil laboratories of soil divisions (branches of the Soil Service), and scientific and planning organizations in the entire Soviet Union.

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[1] In publishing this article the editorial office of this journal hopes that it would find response and would promote the discussion of the problems involved in the training of soil scientists in the pages of this journal.

According to the data for 1956, the planted area of the Republic and regions which are primarily occupied by sod-podzolic (or similar) soils, is about 35 million hectares. If we should analyze only 1 soil sample per 10 hectares, the total number of samples to be analyzed would be rather impressive — 3.5 million. To determine only 4 factors (pH, nitrogen, phosphorus, and potassium) we would have to make 14 million individual determinations. By calculating this for the entire territory of the USSR, we will find that in 4-5 years we will have to make not less than 75 million individual determinations. We did not include fallow, hay fields, and other land uses requiring chemical soil investigations in these calculations. Moreover, we did not consider the necessity in certain cases of a thorough analysis of the material collected in the field, such as plants, fertilizers, agricultural products, etc.; and of investigations, conducted by scientific-research institutes, for the purpose of irrigation, drainage, etc. All this forces us to at least double the volume of analyses, which would amount to 150 million determinations, and this estimate is hardly too high.

The question naturally arises whether the soil organizations are ready for such type of work.

The annual output of one soil analyst using rapid methods of analysis is 8000-15,000 individual determinations, or, taking a maximum 60,000 determinations in 4 years. Consequently, the minimum staff of soil analysts, working only on serial rapid determinations, must include not less than 2500 to 3000 people for the entire Union; 8000-10,000 people would be more realistic. The nature of the training of young specialists is determined by the set task itself.

Most of the laboratory workers concerned with mass determinations must be soil chemists by education, who are familiar with the principles of soil science (including field investigations), and at the same time are properly trained for independent analytical work. A member of a soil analytical laboratory cannot remain at the level of a laborer who mechanically conducts standard analyses according to known specifications. The level of development of Soviet society, the state of science, practical work, and life itself present high requirements to such a worker. A soil chemist must know how to equip a laboratory with the necessary equipment and reagents, how to select and evaluate methods of soil analysis, and, sometimes, how to modify them to suit local conditions, how to make decisions concerning production on the basis of analytical results, and participate in the development of agricultural practices and agricultural melioration methods.

At the same time we know that the most rapid and progressive methods of soil analysis, used at present in many laboratories, are based on the most recent achievements in physical and chemical sciences. This makes it necessary that a laboratory technician know the modern achievements in physics and chemistry. He must also know the construction and use of various instruments. Reliable mass determinations of potassium in soils became possible after the development of flame photometry, but one must know the laws governing atomic radiation in the flame, the theory of the operation of a mirror glavanometer, etc. in order to use the method properly, not allow serious errors to occur, and improve the quality of the determinations. The analyst must know how to find and repair small instrument breakdowns in order not to delay work by waiting for the instrument to be repaired. And what is more, many laboratories do not use flame photometry to this day. At the same time a well-trained soil chemist can assemble a simple device for flame photometry himself, which consists of easily obtainable instruments and parts: a mirror galvanometer, light filters, photoelements, and a gas burner. The same can be said about the potentiometric pH determinations with a glass electrode, the determination of soil salinity with a salt meter, various polarographic determinations, etc. The use in analysis of organic reagents, which have not been fully appreciated as yet by soil scientists, accelerates the determinations in a number of cases and makes them more precise. This is especially true where small amounts of substances and mixtures, complicated in composition (such as soils and many other natural substances), are involved. The proper selection of corresponding reagents and optimum conditions for analytical procedure is possible only when the member of a laboratory has the required qualifications.

To utilize all the possibilities made available to soil scientists at the present time by related disciplines, soil laboratories must be staffed with specially trained workers. It is clear that such specialists can only be people who have had an education in soil chemistry. The replacement of soil chemists by chemists is not successful, as shown by laboratory experience, since a chemist does not know the peculiarities of soil and other similar substances and the specificity of methods of chemical analysis as used in soil science and agricultural chemistry.

At the same time, soil scientists are faced with another, not less important task in the field of theoretical soil chemistry. Great progress has already been made in the study of the chemical and physicochemical properties of soils, secondary minerals, organic matter in soils, adsorption capacity, etc. These achievements promoted the clarification of many genetic and production problems. In summarizing the development of soil chemistry and physical chemistry in the USSR in the last 40 years, I. N. Antipov-Karatayev wrote: "A considerable progress has been made in methods of investigating problems of soil genesis during the Soviet Period of the development of soil science, as a result of the appearance of such methods as X-ray analysis, electronography, thermal method, and electron microscopy..."[2] The use of these methods widened our knowledge of the minerals composing the solid phase of soils and their transformations during the soil formation process. Without these methods we would never have been able to determine the mineralogical composition of finely dispersed fractions, and to identify and study the structure and properties of soil minerals.

Methods of spectral analysis, which are just now being introduced into the practice of soil investigation, are of tremendous importance and open wide prospects for the future. It is quite obvious that spectral emission analysis will save money, time, and work in the determination of the total chemical composition of soils and individual mineral components. Only the first attempts are being made in this direction. Much effort must be spent to develop simple, reliable quantitative methods for the spectral determination of all elements of interest to soil scientists. But these efforts will be well rewarded in the future.

Even more important from the point of view of the study of the chemistry of the soil formation process are methods of spectral absorption analysis. Such important experiments as those using infrared spectrometry in the study of the structure of humic substances and secondary soil minerals can serve as an example. Absorption spectrometry is now one of the most rapid and reliable methods of identifying individual components and determining them quantitatively in complex mixtures without breaking them down; it shows the picture of the mechanics of chemical action directly and makes it possible to work with samples without disturbing their natural condition. The last fact is very important in the study of soils and biological material.

Chromatography, the achievements of microchemical analysis, potentiometric methods (the determination of the activity of salts and ions, phase potentials, for instance), calorimetry (the basis for the evaluation of the energy of soil processes), diffusion methods, centrifuging, etc. are far from being fully utilized by soil science.

We must mention another problem that has concerned soil scientists as well as specialists in other fields — that of microelements. The basic problem is the development of methods for determining elements which are contained in soils and plants in microscopic and ultramicroscopic quantities. A satisfactory solution can be obtained here only on the basis of the newest physicochemical methods: spectrometry, polarography, X-ray analysis, and the use of the newest achievements of analytical chemistry.

Methodological work in the field of soil analysis is being conducted on a limited scale as is the use of modern methods. Methods of chemical characterization, used during various soil investigations (for mapping, agricultural-chemical characterization, melioration, genetic investigations), have not been standardized yet.

Neither chemistry nor physics develop methods for their direct use in other scientific fields, such as biology, soil science, geology, metallurgy. The utilization of physical and chemical methods requires laborious preparation: elaboration, and the determination of their suitability, depending on the object and purpose of the study. These problems can be solved only by a specialist in the given field.

The successful development of biology in the last 20 years is attributable to the effective and qualified use of the achievements in related sciences, the development of chemical and physical methods applicable to the study of biological material, the training of specialists in biological chemistry and biological physics, and the close cooperation of specialists in the related disciplines.

Without touching on the individual problems of soil science and the possibilities for study, we come to the conclusion that the methodological basis of soil science and the theoretical principles of soil chemistry must develop as fast as possible.

Without this development soil science runs the risk of soon lagging behind the other related disciplines and of becoming a science of the past. One of the most important links in this development is the training of specialists. First of all, the chemical, physical, and mathematical training of soil scientists must be improved radically. Moreover, there is a great need in training specialists in soil chemistry; this necessity ensues from the tasks of modern soil science, described earlier. The training of such specialists would permit us to achieve the following:

1. The periodic chemical characterization of soils in every agricultural region for production purposes.

2. The development of rapid chemical and physico-chemical methods of soil analysis for the purpose of chemistry and melioration.

3. The development and introduction into the practice of soil investigations of modern methods which make it possible to study the structure and transformations of the mineral and organic portions of the soil, their interaction and the role of biosynthesis in the process of soil formation, and the development of soil fertility.

4. The development of the theoretical principles of the chemistry (and biochemistry) of soil processes on the basis of the modern achievements in a number of related sciences, such as physics and chemistry.

At present, universities are training soil scientists with a wide background to be employed primarily in field work — the mapping of soils. Having studied the elements of chemistry, and chemical and physico-chemical soil analysis, these specialists conduct soil analyses and analyze problems of soil chemistry. Experience has shown that when specialists are trained in one field only (one and the same curriculum during all 5 years of study) they cannot study soil chemistry thoroughly enough and master the most important modern methods of analysis and investigation. Now it becomes possible to teach a small group of students a wide range of chemical and physicochemical disciplines. Specialists, trained under such a program, must later form the basic cadres of analytical soil laboratories in regional and territorial administrations, at agricultural experiment stations, and in many scientific-research institutes. From these, cadres of highly qualified soil chemists will be established, which is very difficult at present in view of the poor training of students in mathematics, physics, and soil chemistry.

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[2] Pochvovedeniye, No. 11, 1957.

It is expedient to train soil chemists in universities, especially Moscow University, where all the facilities are available. In particular, Moscow University had been training such specialists for a long time. A. N. Sabanin, the founder of soil science at Moscow University, and his students — V. V. Gemmerling and Ye. P. Troitskiy, taught chemistry and soil analysis, and participated in the study of the soil formation process by modern methods, the study of organic matter, adsorption capacity, and other problems of soil chemistry. Many Moscow University graduates of this period are now successfully employed in the field of soil chemistry in a number of institutions of higher learning, scientific-research institutes, and agricultural experimental establishments.

The curriculum of "soil science" has changed considerably in the last 15-20 years, first of all in the direction of a poorer general theoretical training (mathematics, physics, chemistry) and chemical soil analysis. The achievements of Soviet soil scientists in the field of mapping and regional soil study have received general recognition. However, the state of experimental soil science causes concern. Therefore, we must consider the training of soil chemists as one of the most important tasks of soil science. This training must, of course, be based on a good knowledge of soil science, biology, and agronomy. In relation to this, the first two courses in soil science in universities can remain general for all the soil science students, however, they must stress mathematics, physics, and chemistry (primarily analytical chemistry). The specialization in soil chemistry must begin in the third course, retaining the former training in soil science, biological disciplines (with a stress on biochemistry), agronomy, and geology.

The training program for soil chemists must take into account the newest achievements in related sciences and must include all the new methods of analysis and investigation being currently developed. The curriculum of the third to fifth course must include, in addition to the common disciplines taught in the departments of soil science, the following subjects; physical and colloidal chemistry (expanded course), the chemical analysis of soil, plants, and fertilizers, biochemical analysis, spectral analysis, polarography, X-ray analysis, electron microscopy, potentiometry, chromatography, radio chemistry, problems of technical measurements, the theory of errors, organization of laboratories, expanded courses on soil chemistry and physics, and the site quality of soils. Each of the foregoing subjects must be taught from the point of view of the applicability of the methods and concepts to soil investigation. A trained specialist must not only understand the theoretical problems of soil science and soil chemistry, but must be a good practical worker, a highly-qualified laboratory worker, be acquainted with glass blowing and carpentry, electrical and radio engineering, and be able to assemble the necessary instruments and repair them.

The training of soil chemists according to such a program would undoubtedly accelerate the development of soil science and be of great help to socialistic agriculture.

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TRAINING OF SOIL SCIENTISTS

P. G. ADERIKHIN

The problem of the proper utilization of natural resources in our country has become especially important in relation to the tremendous development of industry and agriculture. The solution of this problem calls for: 1) a thorough and systematic study of natural resources everywhere; 2) their accurate quantitative and qualitative assessment in all the republics, regions, Oblast's, and rayons; 3) the interference of man in natural processes to modify them to suit the desired purpose; and 4) the proper planning of the utilization of the resources in the national economy.

One of the most important gaps in the work of agricultural scientific-research and experimental institutions is the lack of soil departments in their system. Because of this, the foregoing institutions are not able to study soils thoroughly as the basic means of agricultural production, and all the agronomical problems are solved without taking soils and their properties into consideration. The Dokuchayev Agricultural Scientific-Research Institute and the State agricultural experiment stations of the Central Chernozem Belt can serve as an example of this. Neither the Institute nor the experiment stations, especially experimental fields, have specialized soil departments, even though they have existed 25-30 years ago and have conducted serious scientific-research work in the field of genetic and agricultural soil science, which helped to solve agricultural problems and facilitated the introduction of the achievements of agricultural science into kolkhoz and sovkhoz production.

As we know, the improper use of soils and improper agricultural practices lead to soil deterioration, reduce the arable land, and lower soil fertility. This can be substantiated by many observations in the Central Chernozem Belt, where intense erosion develops in many regions as a result of improper soil utilization. The systematic and thorough study of soils (for agricultural purposes) must be carried out by the soil departments (regional) of agricultural administrations, and territorial experiment stations, which must be provided with highly-qualified, theoretically well-trained soil science specialists.

The State Planning Commission and the Ministry of Higher and Secondary Specialized Education of the USSR must expand the training of soil scientists and increase the enrollment of soil departments in universities.

Until now highly-qualified soil scientists were trained at State Universities and partly at agricultural institutions of higher learning. S. N. Taychikov[1] recommends that the training of soil scientists be transferred from universities to agricultural institutions of higher learning, motivating his view by the fact that the universities are separate from agriculture and therefore do not connect soil investigations with the solution of the current problems of sovkhoz and kolkhoz construction. It is perfectly clear that Taychinov is not acquainted with the training of soil scientists at universities. To substantiate this and show that the concern of Professor Taychinov is unfounded, let us examine the training of soil scientists at the Voronezh State University.

The Voronezh State University has been training soil scientists since 1946. The Chair of soil science, which was established at the university in 1936, had been and is still conducting its investigations, even the theoretical ones, in accordance with the demands of agriculture. Field studies and production practices were conducted exclusively in the fields of kolkhozes and sovkhozes. Since 1946 the teachers and students of the Chair had studied and mapped the soils of kolkhozes and sovkhozes in various republics and Oblast's of the Soviet Union, covering an area of about 5 million hectares.

While conducting their practical work under the supervision of instructors, the students participated in the scientific-research work of the Chair and thus helped kolkhozes and sovkhozes in the solution of current agricultural problems.

In 25 years of existence, the Chair of Soil Science of the University solved only agricultural problems. It studied the interaction between chernozem and other soils and fertilizers in order to increase their effectiveness. After the Government decided in 1947 to develop irrigation in the arid regions of the chernozem zone, the Chair studied the influence of irrigation on the biological, physiochemical and agricultural properties of chernozem soils by conducting field experiments for a number of years in the kolkhozes and sovkhozes of the Voronezh Oblast'.

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[1] Newspaper "Sel'skaya zhizn'," October 9, 1960.

In 1948, after the Central Committee of the Party and the Soviet Government decided to reclaim the southern and southeastern regions of the USSR, the Chair studied soils suitable for state and kolkhoz forest belts, as well as the influence of already existing forest belts on the soils and their fertility. A detailed complex study of the natural and agricultural conditions of the Gremyachen rayon, Voronezh Oblast', was conducted by the Chair of Soil Science of the University in order to utilize properly, and on a scientific basis, the soil, plant, and water resources of the rayon and rationally plan its agriculture. This work played an important role in the economic and cultural development of kolkhozes and sovkhozes. In cooperation with the Voronezh Zonal Commission and the Zonal Commission of the central-chernozem regions on the development of agriculture to increase the agricultural production from 100 hectares of plowed land, members of the Chair together with practical soil scientists developed a scheme in 1956-1957 of the soil-climate regionalization of the Voronezh Oblast' and the Central Chernozem Belt. These schemes served as a basis for the regionalization of various agricultural and meliorative practices in agriculture. In the last 3-4 years, in cooperation with plant industry, the chair has been studying sandy soils and flood-plain lands for the purpose of developing scientific means of utilizing them in the agriculture and forestry of central-chernozem regions. At the same time certain members and students of the Chair are studying erosion processes and their control.

From 1960 on the relation between the Chair of Soil Science and agricultural production has become even closer. To help the agriculture of the country more actively and concretely, and to prepare soil science students for the requirements of agricultural production, the Chair signed an agreement with the Regional Agricultural Administration of Yaroslav Oblast' to conduct field investigation and compile a large-scale map of the soils of local kholkhozes and sovkhozes. The work is conducted by the teachers, aspirants, and graduate students of the Soil Department of the University. By learning and practicing during the expedition under the supervision their teachers, the students participate in the scientific-research work of the Chair and by their work concretely help kolkhozes and sovkhozes. They compile soil maps, agricultural cartograms, and outlines with recommendations on the proper utilization of the land.

The foregoing example categorically repudiates the statement of Taychinov that universities are separated from agriculture and its current tasks.

As far as we know, other universities in which soil scientists are trained (Moscow, Leningrad, Rostov), are also closely associated with agriculture in their educational and scientific activities, and work hard on the problem of the "Scientific principles of the rational utilization of soils and methods of increasing their fertility."

The opinion of S. N. Taychinov, that the training of soil scientists should be transferred from the universities to agricultural institutes, is unfounded.

Because we know the structure of universities and agricultural schools of higher learning, we are firmly convinced that universities offer better conditions for the training of soil scientists and the development of soil science as a science. As we know, the development of soil science is based on the theoretical achievements of such sciences as biology, chemistry, physics, geology-mineralogy, geography, philosophy, and economics. These sciences are well represented in corresponding chairs and laboratories at universities, their research exerting a positive influence on soil science. All the faculties of natural sciences at universities have well-equipped chairs and laboratories, where the students conduct their laboratory work and become acquainted with methods of investigation and modern instrumentation, which is very important for the training of a soil scientist — a future scientist, or practical worker.

In addition to well-equipped laboratories, the biological-soil faculties of universities have their education-scientific stations, such as agricultural-biological and zoological-biological stations, reservations, botanical gardens, etc., where the soil science students conducted their practical undergraduate work. There are chairs of agronomy at biological-soil faculties, where soil science and students obtain the necessary theoretical and practical knowledge of agricultural disciplines according to the curriculum.

Furthermore, the students get their field practice in kolkhozes and sovkhozes, i.e., under production conditions. Agricultural institutions of higher learning, on the other hand, with the exception of perhaps the Timiryazev Agricultural Academy, do not have the necessary facilities for the training of soil scientists.

The previous statements prove that soil scientists must be trained primarily at universities. Soil scientists, graduated from universities, are well acquainted with soil genesis and classification. They can conduct field investigations of a high quality and map soils for land management, agricultural planning, forest management, liming, application of gypsum, drainage, irrigation, and agricultural melioration, and work independently at agricultural soil laboratories, scientific-research institutes, and agricultural experiment stations.

In order to determine the quality of the training of soil scientists, the Chair of Soil Science of Voronezh State University sent a questionnaire, several years ago, to regional and territorial agricultural administrations where the students who had graduated from the university were sent to work. All the administrations gave good references to the soil scientists. An indication of the high quality of training of soil scientists at universities is the following fact. Many soil science students who were doing their graduate practical work were offered permanent positions where they were practicing.

The foregoing indicates that the soil departments of universities not only produce well-trained soil science specialists and, consequently are well able to cope with the problems facing them, but universities are the only institutions of higher learning able to give soil scientists highly-qualified theoretical and practical training. This is precisely the type of soil scientists that our country needs, instead of practical workers with an insufficient knowledge of theory, as suggested by S. N. Taychinov.

REVIEWS

VALUABLE INSTRUCTIONS ON THE THEORY AND PRACTICE OF THE USE OF MINERAL FERTILIZERS[1]

A. V. PETERBURGSKIY

As we know, the production of mineral fertilizers in the USSR will have increased threefold by 1965, as compared to 1958, and will reach 31 million metric tons (as reduced to standard fertilizer). Thereby the proportion of concentrated, mixed, and complex fertilizers, which are much more economical than the presently used simple forms of fertilizers (containing only one of the three major plant nutrients), is increasing considerably. The physical properties of standard fertilizers will be improved. For instance, all new forms produced will be granular, which will facilitate their use in various ways; large amounts of liquid nitrogen fertilizers will be produced; and the production of fertilizers containing microelements (molybdenum, boron, manganese, copper, and others) will be increased.

To utilize these important means of increasing crop yields and improving the quality of crops and with the maximum effectiveness, we must sharply increase the level of agricultural-chemical practices in our agricultural production, and increase the knowledge of soil chemistry, fertilizers, and plants to the sovkhoz and kolkhoz agronomists.

The study of the book being reviewed, which was published by Sel'khozgiz at the end of last year, will be of great help to specialists of socialistic agriculture. It was compiled by 39 authors — most of them scientists known by their papers on definite problems of agricultural chemistry.

The handbook consists of 4 main parts and 8 sections:

I. Agricultural-chemical principles of the use of fertilizers.

II. Fertilization of agricultural crops.

III. Methods of investigating fertilizers.

IV. Production of mineral fertilizers.

The first two parts comprise 70% of the test.

First section "Chemical elements in the life of plants" gives a summarized, but clear account of the basic nutrition of plants, their requirements for various chemical elements, and compounds containing these elements in the soil. One of the shortcomings of this section is the fact that a considerable part of the material on the dynamics of nutrient uptake by plants is based exclusively on foreign sources: these materials were obtained under different climatic conditions. Such data are lacking altogether for certain important crops (sunflower, alfalfa, grain crops, buckwheat, soybean, castor-bean, mustard, etc.). Table 9 on page 25 gives data characterizing the uptake of nitrogen, phosphorus, and potassium by 1 metric ton of the marketable surplus of various crops. This is good, but it should have been explained that this also includes the non-marketable production without which there would be no marketable surplus. Otherwise the data on the uptake are obviously not complete.

Second section "Mineral fertilizers and their properties" briefly characterizes the chemical and physical properties of all the macro- and micro-nutrient fertilizers being produced and to be produced in the near future, an idea is given as to how they are manufactured, and examples are presented from many experiments on the relative effect of various forms of the most common mineral fertilizers on certain plants in relation to soil conditions.

It must be noted that the assortment of phosphate fertilizers in the USSR includes the so-called phosphate slag; to our amazement we could not find this term in the Handbook. "

Potassium-containing minerals such as kalussite and others were left out of table 68 (p. 121), even though they are found in the deposits of our country, and our literature has described experiments with them. Kieserite is mentioned in the same section (p. 123), but its composition is not given. The "Handbook" does not mention kalimag and kalimagnesite fertilizers, which contain different amounts of potassium and magnesium sulfates.

The description of the interaction between potassium fertilizers and the soil is very brief and does not even mention the non-exchangeable adsorption ("fixation") of potassium by the soil, even though it is common and has a negative effect on the availability of the potassium added to plants.

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[1] "Handbook on mineral fertilizers," edited by M. V. Katalymov, L.I. Korolev, A.V. Sokolov, F.V. Turchina, and T.P. Unanyants. Sel'khozgiz, 1960. 551 pp.

The use of molybdenum for the fertilization of leguminous crops on acid soils is not mentioned at all. At the same time, ammonium molybdic acid was used on almost 500,000 hectares in 1960, i. e., over an area much larger than that of all the micro-nutrient fertilizers mentioned in the book.

Third section "Natural conditions and the use of fertilizers" contains information on soil properties in the Soviet Union, agricultural soil regions, soil microorganisms, and their life activity. All this is necessary in such an instruction manual and is competently written. But we must note that the section as a whole has little relation to the problems of fertilization and in this sense looks out of place. The concept of soil fertility is not sufficiently elucidated. The inclusion on p. 173-176 of a general systematic list of soils is hardly justified. Without explanation such a list gives nothing to an agronomist that he could use for the rational utilization of fertilizers. Problems of the fertilization of podzolic, sandy, water-logged, and bog soils (pp. 207-210) are artfully appended to this section, the more so since no such generalization is made for the rest of the soil groups.

Fourth section "Agricultural practices for the application of fertilizers" shows the importance of crop rotation, the level of agricultural techniques, irrigation, methods of adding fertilizers, and certain other factors to the effectiveness of mineral fertilizers. It also includes the liming of acid soils and the application of gypsum to solonetzes, as well as the use of furnace ash. In our opinion, there should not be such a conglomeration, and the problem of the chemical melioration of soils should be treated separately and in more detail. We cannot consider the application of lime and gypsum only as a background for the better effect of mineral fertilizers. Chemical melioration is undoubtedly of great importance for increasing soil fertility.

Fifth section "Fertilization of individual crops" is the main section of the Handbook. In it the reader will find a generalization of experiments on the combinations, amounts, forms, dates, and methods of adding fertilizers (including organic fertilizers) to various crops grown in the Soviet Union.

Much attention is devoted to this most economical method of using fertilizers, especially before sowing. The material in the section convincingly shows the great role of mineral fertilizers in high crop yields. At the same time we can see that many important aspects of the application of fertilizers to a number of crops have not been studied sufficiently. This is particularly true of fruit, berry, and citrus crops, grapes, ester oil-bearing plants, new fibers plants, etc. Unfortunately, the Handbook does not say anything about the fertilization of medicinal and ornamental plants.

The end of this section contains general materials on the need of soviet agriculture for mineral fertilizers (including the largest natural regions), on the need for mineral fertilizers in the current 7-year plan, the expected increase in the assortment of mineral fertilizers, and the use of complex and mixed fertilizers. As we can see from this list, the foregoing subsection could have been an independent section in the book.

Sixth section "Methods of investigating fertilizers" includes: the agricultural-chemical analysis of soils, methods of rapidly diagnosing deficiencies in the mineral nutrition of plants, and the characteristics of field experiments with mineral fertilizers.

Seventh section "Analysis, storage, and mixing of fertilizers" is not objectionable.

Eighth section "Manufacture of mineral fertilizers" includes standards for fertilizers and statistical data on the production of fertilizers in the USSR, and other socialistic and capitalistic countries. There is a contradiction on page 514: the production of mineral fertilizers in Russia in 1913 was 89,000 metric tons, while on page 3 only 69,000 metric tons are mentioned. There are discrepancies in terminology in certain cases. Sodium nitrate is sometimes called soda nitrate (p. 92, 145, 450, 550, etc.). We can hardly agree with the term "need" of soils in liming (p. 427). Soils as such do not "need" anything. Man needs to grow certain crops. We mentioned these small roughnesses for the authors to consider in preparing the next edition of this valuable book. Altogether the evaluation of the book is good.

A book of this type on organic fertilizers would be desirable.

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